CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

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A MONTHLY JOURNAL for Engineers, Architects, Surveyors & Contractors and all interested in Cement, Concrete, Reinforced Concrete, Fire-resisting Construction and Structural Steel.

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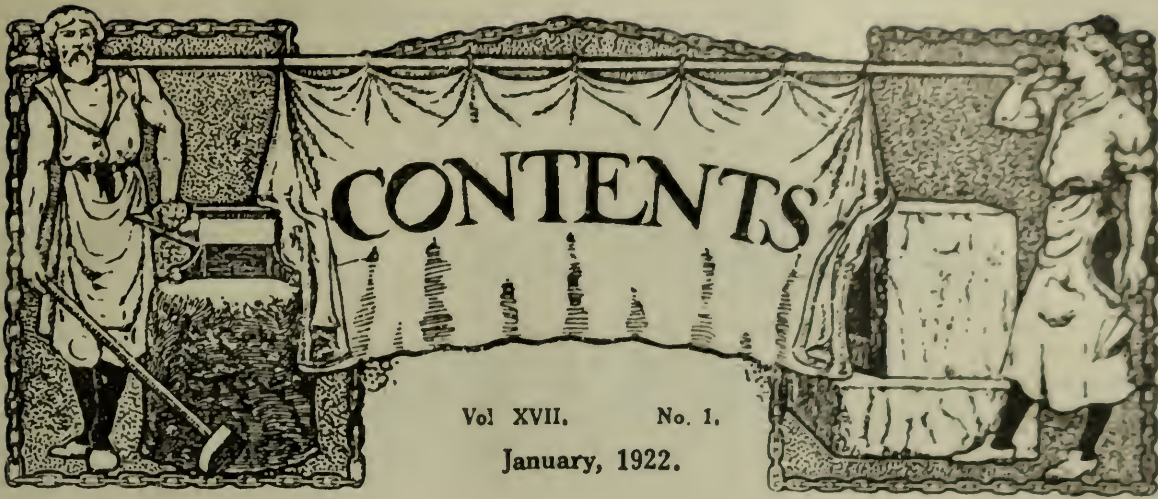

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CONCRETE AND CONSTRUCTIONAL ENGINEERING

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EDITORIAL NOTES.

THE ORGANISATION OF THE CONCRETE INDUSTRY.

FROM a careful perusal of the notes which will be found elsewhere in this issue, dealing with "Some of the Uses of Concrete during 1921," it will be seen that a steady development and constant progress are being made in the use of this material, and that in this branch of industry, as in most others, there is no finality either in use or practice. Year by year new uses are being discovered, and year by year concreting practice is improving through patient research and as the result of past experience.

THE NEED FOR ORGANISATION.

It will be noted that, excluding contractors who are engaged in concrete work on a large scale, there are in the United Kingdom some 260 firms who either produce concrete goods or erect concrete structures, and about sixty who supply concrete moulds or machinery. These numbers represent but a small fraction of those who are actively engaged in concrete work, and the thought at once jumps to the mind that here we have a distinct and definite industry which not only possesses no organisation of its own, but for which no systematic education has yet been provided. And when we consider the dimensions to which this industry has now attained, and the possibilities—or more than possibilities—which lie before it, the need for education and organisation are apparent. This subject was dealt with by Mr. E. Fiander Etchells in his recent Presidential Address to the Concrete Institute, summarised in our last issue, in which he laid down the broad lines upon which this end might be accomplished.

Mr. Etchells, referring to the formation of a block-setting Union, said: "We of this Institute can hardly put forward this suggestion, because, as a scientific body, we do not deal with trade or politics." True. Up to a certain point, we agree. But, we think that the Concrete Institute being what one might term the National authority on concrete matters in this country, should take active steps to set the machinery in motion.

It is clear that in the present state of flux in the labour world any new industrial organisation will of necessity have to be formed on principles very different from those which have hitherto obtained, and we are strongly of the opinion that here the concrete industry has a magnificent opportunity of showing what could be done in organisation on modern lines and in conformity with the spirit of the age. Such an organisation as we have in mind would be of a co-operative nature, in which all its members were working together for the common good, and would include the brain worker, the manufacturer and the artisan.

We should suggest that, as a first step, the Concrete Institute call together a meeting of representative men from amongst concrete engineers and designers, architects, contractors, concrete manufacturers and workers, and block-setters, with a view to a discussion of the whole question and a consideration of the best means by which the end in view may be attained.

THE NEED FOR EDUCATION.

The education of the concretor was another important matter touched upon in Mr. Etchells's address. This question is closely associated with that of the organisation of the industry. If, as we contend it is, concrete work is now a definite and individual industry, provision should be made for the systematic education of its workers. We gladly recognise the valuable work that is being done in certain technical institutions, but the fact remains that the education of the concretor is mainly left to chance. This is not as it should be. We cordially agree with Mr. Etchells that in the curriculum of the various technical schools and institutes throughout the country, concrete should be regarded as an independent subject, and courses in both theory and practice arranged accordingly. How this might be brought about was outlined in the address, and we feel strongly that the first move in this direction could only be made by the Concrete Institute.

With the co-operation which would result from the organisation of the industry and the recognition on the part of the educational authorities of concrete as a separate subject, a force would be created which would tend to develop higher standards and raise the level of efficiency.

AMERICAN ARCHITECTURE.

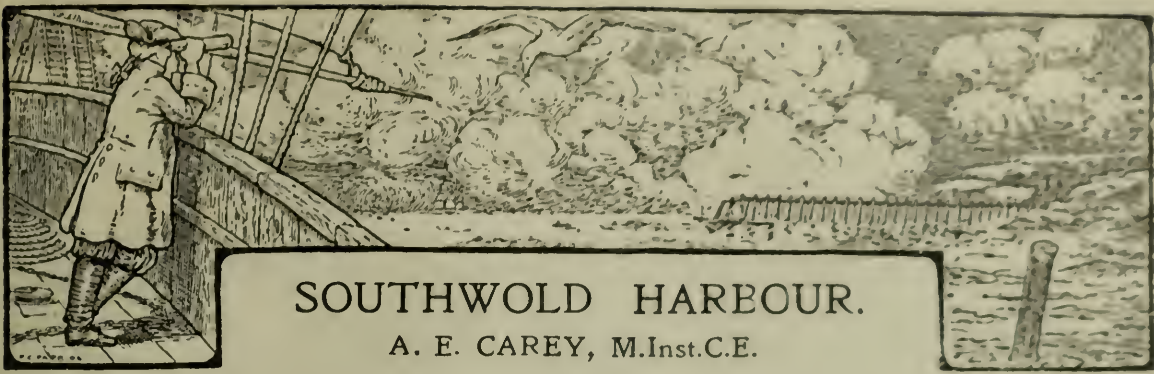
WHETHER it was coincidence or forethought—we suspect a combination of the two—that synchronised the exhibition of American architecture at the R.I.B.A. with the disarmament conference at Washington, the incident affords a happy augury for future relationships between the great countries ; a fact that Lady Astor, M.P., was quick to realise when, in the course of performing the opening ceremony, she said, " I think America and England should remember that it is taste that unites countries, not treaties." There is a very close parallel between the relationship of the American to the Englishman, and of American architecture to English architecture. It is no rare event for Americans of more thoughtful disposition to experience, on arriving in England for the first time, a strange feeling of kinship; the visit assumes the aspect of a familiar return rather than a new adventure. So, too, the American architect is at once aware that he is amongst the prototypes of his own great national architecture, for the French influence that is now so marked in American architecture is a comparatively modern growth and dates from the World's Fair of 1893, from which date the great name of McKim emerges, and from thence onwards the influence of the Beaux Arts tradition becomes more prominent. America has assimilated the best from Europe, and, the intervention of the Atlantic giving just that distance of vision necessary for freedom from sentiment, has boldly and splendidly converted it to her own ends. Thus it is that we find in some of the smaller works of domestic architecture a delightful harmony between French and English elements that would be impossible in either of the countries of origin. The transplantation of Gothic, however, does not seem to have met with such success. The reason may be that the beauty of Gothic is so largely the result of its very definite structural limitations, and in its history the gradual surmounting of these limitations is to be traced. To-day they have been entirely transcended, owing to the development of new materials, so that to build a Gothic structure, retaining these limitations, becomes an anachronism, to build and to ignore them is a sham.

The Englishman, visiting the exhibition, must have been impressed by the greatness of conception, by the scope, and by the opportunity; for architects are limited by the attitude of their age towards architecture. There is, it is true, a certain interaction; opportunities make architects, and architects make opportunities, nevertheless, it must not be overlooked that in America the commercial asset of a fine building is understood; moreover, there exists among the people what may be termed an architectural consciousness which is gradually being created in England, but the process is slow and laborious, and until it is effected we shall continue to have meanness and ugliness in our midst. Meanwhile, we look with envy and admiration at American work, we are astounded at its scale and its prodigality and at that elusive quality which applies equally to architecture as to mankind, and which, in the latter connection, is referred to as *good form*. An aspect of this quality is revealed in the extreme refinement of detail. Particularly is this noticeable in domestic work. Care is expended on such details as the exact texture of brickwork and in its pointing, in the moulding of the smallest architrave, and the graining of a door. Everything assumes a proper degree of importance and receives a proper degree of attention. It must not be assumed that the English and the French are the only European influences to be found in American work, often the inspiration can be traced direct to the source of the Italian Renaissance or, as in the Pennsylvania Railroad Station at New York, one of the greatest achievements of McKim, Mead & White, to Imperial Rome, and here and there Spanish elements are to be observed. The rich diversity of treatment is largely the result of climatic conditions which vary immensely in different parts of the country. It is difficult to appreciate the significance of this influence, accustomed as we are to our own so very limited variations, and viewing work gathered together from all quarters of half a vast continent within the confines of a small gallery.

Yet over all there is a spirit of modernity. The European elements are made to live again because they are synthesised into something new, virile and expressive of a great architecture-loving people. And this boldness of attack is not limited to the designs, but extends also to the handling of materials. No prejudices are allowed to stand in the way of the use of a material if its efficiency be proved. Architecture is, after all, subservient to humanity, and must therefore be subjected to a never-ceasing change. It cannot live in the past and serve the present. Thus we find that the American architect is quick to realise the possibilities of concrete as a material for every class of building, and quick to discover and exploit its æsthetic possibilities. Assuredly we have lessons to learn from America, and we shall be helped in our instruction by exhibitions such as the one recently displayed upon the walls of the R.I.B.A.

NOTICE TO SUBSCRIBERS.

The annual subscription to this journal is now 18*s*. (owing to a printer's error this was given as 18*s*. 9*d*. last month), but single copies will be as heretofore 1*s*. 6*d*. each.



SOUTHWOLD HARBOUR.

A. E. CAREY, M.Inst.C.E.

AMONG the many minor changes which have resulted from the War may be instanced a completely altered attitude with regard to small harbours. In pre-war times the British Admiralty was not friendly to the creation of small ports, the reason being that their whole policy of defence was concentration and, if it became necessary to split up the naval forces in order to defend a number of isolated ports, such action militated against their general policy of massing ships at a few points.

It is obvious that from the economic standpoint the multiplication of small shipping centres is a great boon, as it enables commodities to be delivered up and down the coast so much nearer their ultimate destinations. Water transport being notoriously the cheapest form of conveyance, the creation of distributing ports up and down the coastline becomes a prime end to be attained.

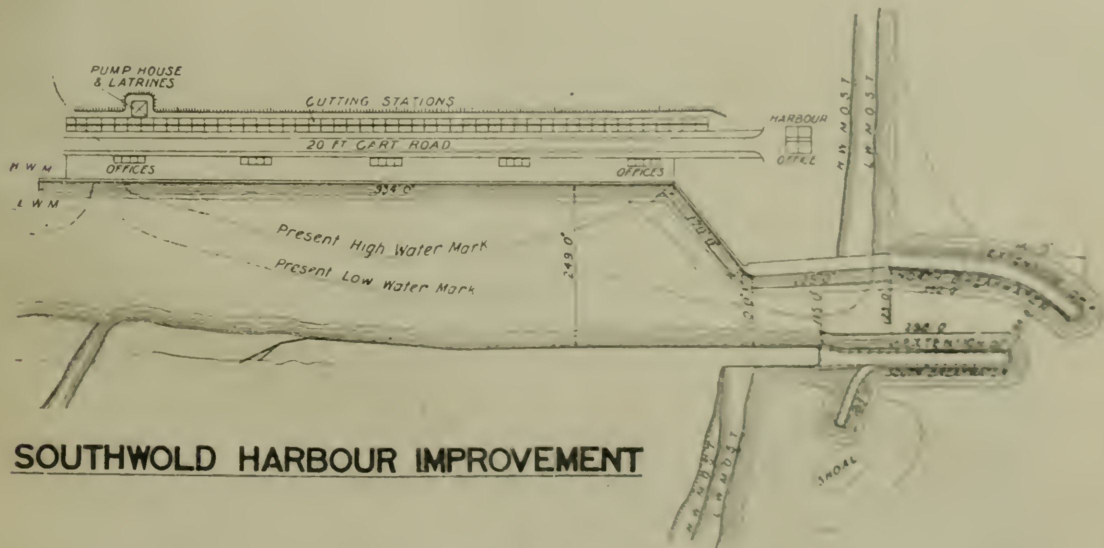


FIG. 1.

This policy of decentralisation has been advocated in every age, and amongst its protagonists may be instanced Sir Walter Raleigh, who in his day strongly urged the strewing of the coastline with small ports, in the interests of the State.

The present altered condition of international affairs renders such a policy far more practicable than would have been the case before the War. The possible overseas enemies of Great Britain no longer count. It is barely conceivable that a combination of sea forces could be massed in European waters to threaten the integrity of the British Empire, Germany and Russia being no longer factors in the problem, and the other great naval powers being allies of this country

Among the most promising developments of minor harbours is that of Southwold in Suffolk. This port is the nearest to the Rhine ports.

It was designed as a fishery harbour, lying as it does in the centre of the best of the herring fisheries. The other ports in the vicinity are greatly congested in the fishing season, and the access to them from the sea leaves much to be desired.

FIG. 2. THE FISH MARKET IN COURSE OF CONSTRUCTION.

FIG. 3. THE FISH MARKET AFTER COMPLETION.

Southwold has deep water close in to the harbour. It, moreover, has ample facilities in respect of land contiguous to the harbour, available for the marshalling of fish traffic on a large scale. It has also the initial advantage of a large expenditure of money, over 25 per cent. of which has been supplied by the British Treasury. This national expenditure, owing to local conditions, is at the present time unfruitful.

The River Blyth is an important waterway, and the volume of water which it collects will, it is anticipated, keep the entrance channel leading up to the port scoured with little or no dredging.

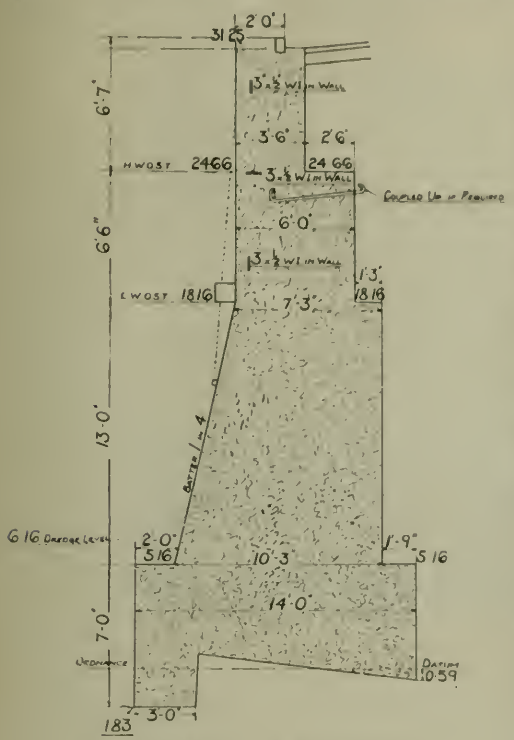


Fig. 4. Section of Quay Wall.

The required facilities for dealing with the problem of unemployment exist on the spot, there being accommodation in the town for the influx of labour necessary. It must also be borne in mind that a fishery harbour provides employment for women as well as men, as the cleaning and packing of the fish in barrels is carried out by women workers.

A moderate expenditure on the extension of harbour facilities and also in improving the railway service from the Great Eastern Railway main line to the harbour, are the requirements of the moment. These, it is believed, could be carried out for relatively a reasonable capital sum. As a result the work already done with national funds would serve a national purpose. The extension could be as extensive or as restricted as the money placed at the disposal of the harbour authority justified.

Fig. 1 represents the general block plan of the harbour as constructed. This consists of 1,000 lin. ft. of concrete quay wall, two timber piers and a connecting wharf between same ; also a roadway 110 ft. wide behind the quay, in rear of which

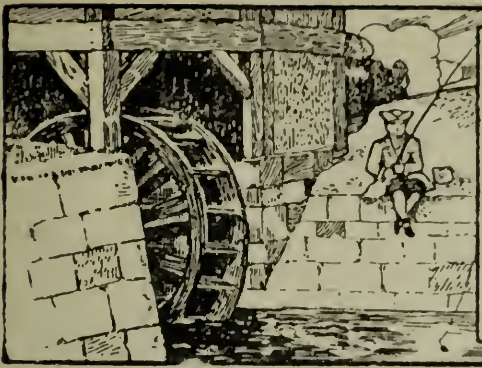
Fig. 5. The Quay in Course of Construction.

road the fish curing plots are located. There is also a fish market (see *Figs.* 2 and 3) which is in every respect up to date with water service (fresh and salt). The quay wall is carried down to a foundation of Glacial Drift of a variable character, consisting in the main of a sandy deposit. A large amount of dredging has been done in the harbour. *Figs.* 5, 6 and 7 illustrate the various stages of the work while in progress. The expenditure on the undertaking to date has been £86,000.

FIGS. 6 AND 7. TWO VIEWS SHOWING THE FINISHED QUAY WALL.

MEMORANDUM.

Concrete Roads in Canada.—That concrete-made roadways have for some time existed and are ever-increasingly popular in the United States of America is well known, but that they are fast becoming popular in Canada may not be so widely understood. It is therefore of interest to learn of such appreciation. Thus the *Empire Review*, in its last issue, writes of Canadian concrete built roads as follows : "Perhaps the finest country roads in Canada are the cement highways constructed by the Ontario Government. In order to carry out extensions, the provincial Government has voted £200,000 to establish their own cement plant."



WALKERBURN HYDRO-ELECTRIC SCHEME.

By W. L. SCOTT, A.M.Inst.C.E.

A FEW years ago, Messrs. H. Ballantyne & Sons, Ltd., of Walkerburn, the well-known tweed manufacturers and owners of the Tweed Vale Mill, took over the adjacent Tweed Holm Mill, and also acquired full control of the water rights of the adjacent River Tweed. Prior to this, about 160 h.p. was being generated from the river by means of undershot wheels. With the greater head of water now at the firm's disposal, the question of the more economical use of this power was gone into, with a view to providing sufficient energy to meet the present requirements of both mills. Consideration was given to many schemes, and it was finally decided to produce the necessary additional electrical power from the river by securing the energy for the whole twenty-four hours, and to store the excess for use during the nine working hours.

In this manner it was calculated that sufficient electrical energy would be obtained, and accordingly, what may safely be described as one of the most enterprising hydro-electric schemes yet attempted in the British Isles was put in hand.

The manner in which the energy should be stored during the time it was not actually required was gone into, and it was found that a more economical method was available than the one usually adopted. The usual practice, of course, is to generate current during the time the power is not required, and store it by means of batteries.

The unique situation of the mills, which lie in the valley of several surrounding hills, suggested a very ingenious scheme of storing the available water-power able to be produced during the night and week-ends, when the mill was not working.

At the top of one of these hills, a site for a large reservoir was chosen, and the scheme which has just been completed and is now in successful operation is briefly as follows :—

The low-pressure turbines, which, during the running hours of the mill generate electricity, are so arranged that when the mill is closed down and the power no longer required, they are utilised to drive high-speed centrifugal pumps, which pump the water through a pipe-line to the top of the neighbouring Kirnie Hill (which is approximately 1,000 ft. above the level of the mills), where it is stored in the large reinforced concrete reservoir, having a capacity of three and a half million gallons.

When the mills commence work in the morning, the low-pressure turbines which have been driving the pumps filling the reservoir during the night, are used directly to generate power for the mills. The water in the reservoir at the top of the hill is now made to flow down the pipe-line, and is diverted to pass through a pelton wheel, which provides an additional horse-power of approximately 200

In this manner the 10 ft. 6 in. head of water, which previously gave in the working hours of the mill about 160 h.p., now gives between the pelton wheel and the new low-pressure turbines, a total of approximately 400 h.p., which is available for use in the mills during the time they are in operation.

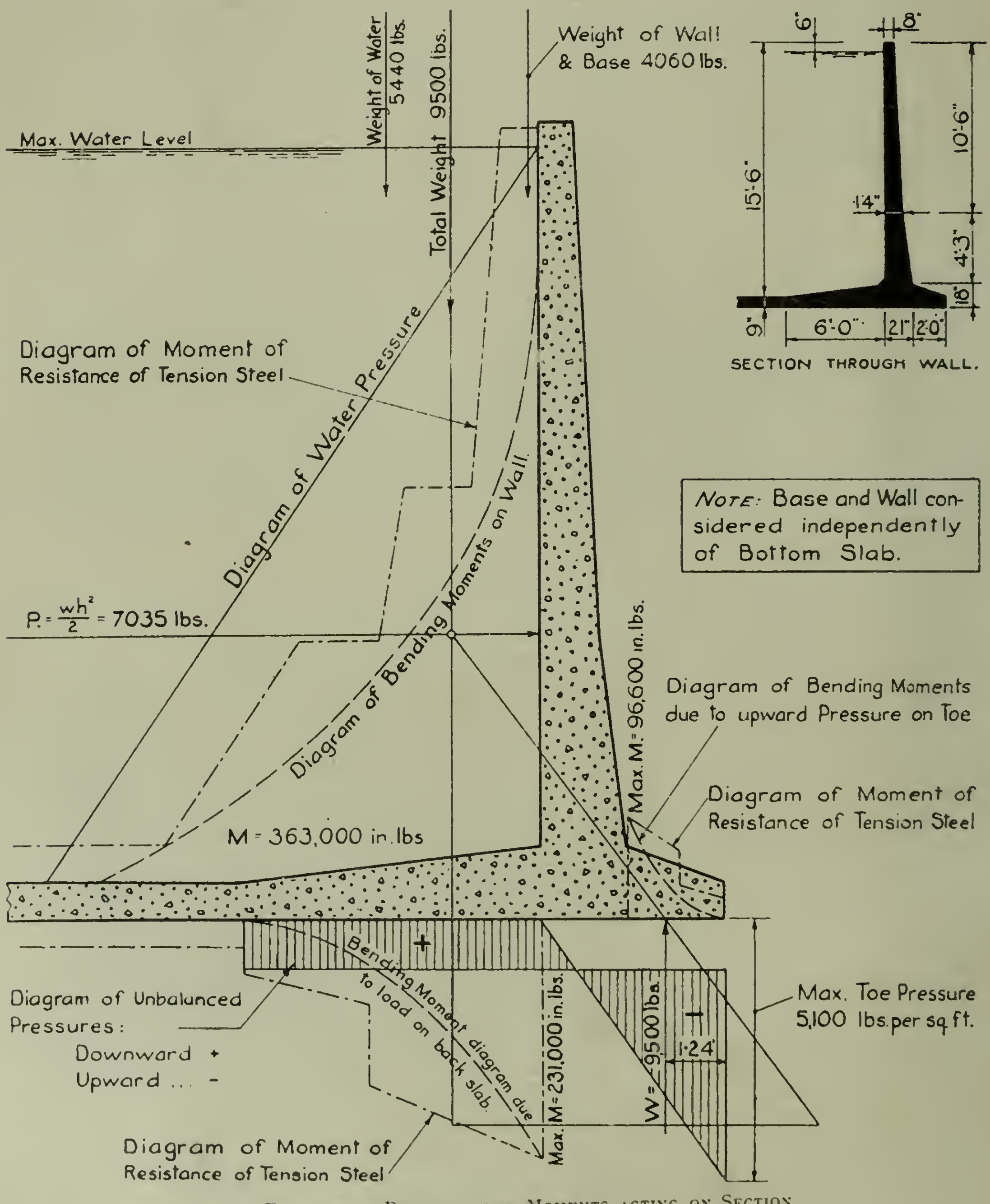


FIG. 1. DIAGRAM OF PRESSURE AND MOMENTS ACTING ON SECTION.

In connection with this scheme, the floors and the various cable conduits to the new power house, and also the large reservoir mentioned above, were constructed of reinforced concrete, and when the designs of these were prepared, particular attention had to be paid to the peculiar conditions under which they were to be constructed.

The construction of the turbine house presented considerable difficulties, as the level of the turbine exhaust pits was about 8 ft. below the level of the River Tweed, and situated in gravel strata about 180 yds. distant from it. This portion

Fig. 2. View of Finished Reservoir.

of the work, therefore, had to be very carefully designed, and the construction carried out with extreme caution, as the turbines work in watertight pockets.

With regard to the reservoir itself, this is situated at a height of 1,497 ft. above sea level, and, as previously mentioned, is approximately 1,000 ft. above the works level. The question of transport consequently presented considerable difficulties, as all the materials and plant required for the work had to be hauled up to the site at an incline of 1 in 3. Over 3,000 tons of aggregate, 400 tons of cement, as well as 100 tons of steel reinforcement had to be hoisted in this manner. This was done by means of a cable track.

Added to this difficulty of transport were the intense cold and violent winds obtaining at the high altitude of the reservoir. In view of this, a plain cantilever type of wall was adopted, the design being kept in every respect as simple as possible, and the stresses in the materials being kept low. The walls vary from 8 in. thick at the top, to 21 in. thick at the bottom. This latter increase, however, is not constant, but becomes greater near the foot of the wall, in a manner somewhat similar to the bending moment diagram. The latter point, although apparently a small one, resulted in a great saving of material, and consequently of cost. An illustration showing a cross section of the wall is given in *Fig.* 1, upon which the pressure, bending moment and resisting moment diagrams, etc., are clearly shown.

On the internal faces of the wall, the maximum tensile stress in the vertical rods has been limited to 6½ tons per sq. in., this being considered as the maximum tensile stress to which the steel should be subjected, in order that there should be no danger of the surrounding concrete developing hair-cracks.

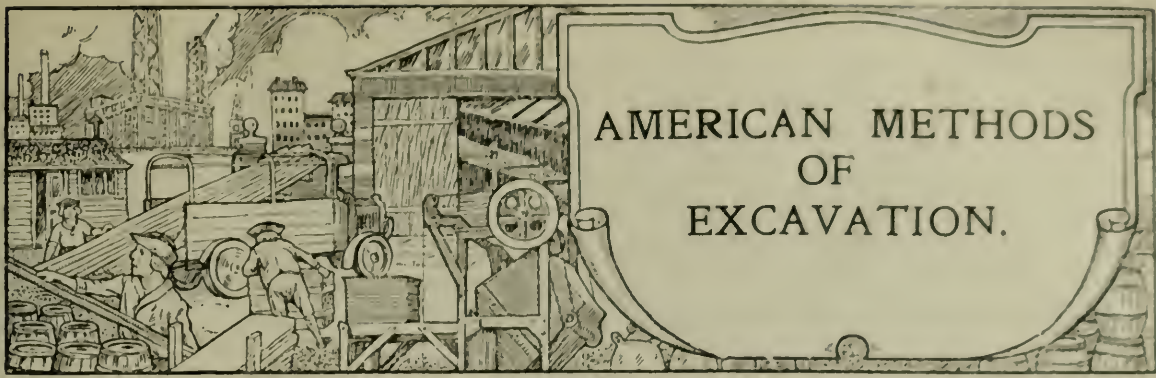
The reservoir is 192 ft. square by 15 ft. 6 in. high, and is provided with a 9 in. bottom slab of concrete resting directly on the solid ground. This slab contains a light mesh of steel reinforcement near its upper surface, arranged so as to take up the tensile stresses produced by changes in temperature.

It may be interesting to state that, although this wall is under a considerable and constantly varying head of water, an ordinary concrete mixture of 1 : 2 : 4 was employed. The greatest care, however, was taken in the choice, grading and mixing of the constituent parts, and it is very satisfactory to know that after some months of use, no leaking or sweating in any part of the structure has been observed.

The laying of the pipe-line and the construction of the reservoir, owing to the difficulties above described, very naturally took considerable time, and work on the reservoir had to be stopped during the first winter, on account of the very severe weather experienced. An idea of the intensity of the gales which blew on the top of the hill may be gathered when it is stated that, on one occasion, a cement shed, which was standing empty at the time, together with a number of tools, was lifted and deposited nearly a mile away in a valley. When these conditions are appreciated, the reader will agree that the above reservoir provides yet a further example that successful construction in this material can be achieved in the face of difficulties usually considered sufficient to prohibit the use of reinforced concrete.

A photograph showing the completed reservoir is given, and from this may be gathered a very good impression of the isolated nature of the site.

The design of the reinforced concrete portion of the work was carried out by the Considère Construction Co. Ltd., of 5 Victoria Street, Westminster, S.W. 1, and the contractors for the reinforced concrete work and the pipe-line were Messrs. Melville, Dundas & Whitson, of 224 St. Vincent Street, Glasgow, while the general scheme was designed, and the mechanical work carried out, by Messrs. Boving, Ltd., 56 Kingsway, London, W.C. 2.



AMERICAN METHODS OF EXCAVATION.

By ALBERT LAKEMAN, M.S.A.

Excavation work can be said to be common to all types of structures, whether reinforced concrete, structural steel, or any other material be adopted, and the methods employed should therefore be of general interest to all architects, engineers and contractors, more especially from the labour-saving standpoint, as the cost and expedition of the work is obviously affected considerably by this phase. An extensive use is made of labour-saving machinery in America and a few typical examples taken from schemes actually executed should prove of interest at the present time, owing to the fact that there is a marked tendency to develop the use of similar appliances in this country, especially in connection with large schemes. The methods employed in excavating can be classified under the following heads :—(*a*) hand labour, (*b*) ploughs and scrapers, (*c*) derrick and skip, (*d*) derrick or crane and grab, (*e*) trench diggers, and (*f*) steam shovels. Many combinations of these methods are used according to circumstances, and it will be clear that the application of the most suitable equipment to any particular section of the work is essential if the maximum economy and speed are to be attained. At first sight some of the methods would appeal to the uninitiated as possessing little if any merit, but a close study of the work performed will show some surprising results as regards low cost when compared with ordinary hand labour. Of the latter method no description is of course necessary, except to mention that if the excavation is any appreciable depth some method of lifting by mechanical means is always employed, and the use of throwing up in stages by hand is not in any way general in America.

Plough and Scrapers.—This may be described as a typical American method and one which possesses a great deal of merit, more especially for surface or shallow digging. It is true that ploughs are occasionally employed in this country in connection with the removal of surface soil, but, as a general rule, the soil after being cut up by the plough is removed by hand labour. When scrapers are employed the surface is first cut up with an ordinary farmer's plough to make it loose, and it is then picked up with the scrapers and removed to the required place of deposit. Two types of scrapers are in general use, the first being merely a flat-bottomed type, like a large scoop, and the second a deeper receptacle of greater capacity that travels on two wheels. An example of the use of the first type is illustrated in *Fig.* 1. The scraper is drawn by two horses attached with a chain on each side of it, and two men are employed, one acting as driver and the other as the operator. When picking up the soil the operator lifts the back of the scraper by means of two handles, thus causing the point to dip down and bite into the earth while the horses are in motion. When the soil rises over the scraper to an extent sufficient to fill the latter the operator presses down on the handles and causes the point to rise to the surface again, and the scraper is then drawn on its flat bottom to the tip. The contents are discharged by the simple operation of lifting the two handles by a quick motion, which overturns the scraper entirely. The operation is a continuous one, as a circular track or route is usually followed, which allows several scrapers to operate behind one another, and as each has a capacity of about one-sixth of a yard cube a large quantity of soil can be removed

FIG. 1. DRAG SCRAPER IN USE.

in a day. These scrapers are also very useful for spreading and levelling a large quantity of any loose material over a large area, as these can be pulled over the heap by the horses, filled near the summit and discharged at the required point. The operation of the wheel scrapers is very similar, but as the scoop portion is mounted on an axle, the depressing of the point into the soil and the overturning of the load is accomplished with a simple lever. The writer has seen some large deep pits excavated by the use of ploughs and scrapers, and the results were surprising as regards economy and speed. In cases of this kind the scrapers are gradually worked down by forming slopes at each end to allow an easy travel for the horses, and the ground is continuously ploughed in advance of the scrapers to keep the ground sufficiently loose. The scraper method of excavation is of course not applicable to work at a low level where the hoisting of the soil has to be done, or in a confined space where insufficient turning room for the horses has to be considered. It is, however, very useful for all grading work and could probably be advantageously applied in this country when preparing the formation for new roads or for levelling building sites of considerable area.

Derrick and Skip.—The illustration in *Fig.* 2 shows the use of a derrick and skip for raising the soil where hand labour is being adopted, and although there is nothing particularly striking about this example it does indicate a typical method of handling the soil. Mechanical means of excavation could have been employed in forming this large pit, but no equipment was available for various reasons, and

Fig. 2. Hand Labour and Wooden Skip.

it was decided to proceed with hand labour. In order to facilitate the removal of the surplus soil, however, a derrick was erected at the side of the excavation which had sufficient travel to enable it to cover the total length, and by this means large flat-bottom wooden skips, which were detachable, were lowered to the labourers for filling and were then hoisted and emptied on to an inclined shoot, metal-lined, which discharged direct into bottom dump waggons drawn by teams of horses. Several of these skips were in use to avoid any waiting on the part of the workmen, and they were so arranged with a chain attachment that easy discharge of the contents is possible, more especially as one end is left open and the skip only needs tilting. These skips are in general use in New York City for hoisting the rock after it has been blasted, when excavating for the basement floors and foundations of the skyscraper buildings, and it may therefore be considered as a typical example of American soil handling. The derrick is not shown in the illustration, but this is usually of any ordinary type with swinging jib having a wide range and generally steam operated with vertical boiler.

Derrick and Grab.—Considerable use is made of grabs or " clam-shell buckets " for removing soil, particularly if this is of a soft or loose nature, and a very general practice is to erect either a stationary or travelling derrick on the side of the excavation, according to circumstances, by means of which the grab is lowered or raised and operated. The photograph in *Fig.* 3 shows a typical example of excavation by this means, where a large pit is being formed. The grabs employed

FIG. 3. EXCAVATING WITH DERRICK AND GRAB.

are of two types, viz. the ordinary bucket form or the orange-peel shape. The former type is illustrated in the photograph, while the orange-peel type is semi-spherical in shape, and it opens into four sections like four pieces of orange peel—hence the name—each of which is pointed at the lower end to facilitate the bite into the soil. When in operation the grab is opened out by the man operating the derrick and then lowered to within a few feet of the surface to be removed, when it is steadied, and at a given signal by the " watcher " it is suddenly dropped on to the soil, when the sharp open edges, which usually have short teeth fitted to them, bite into the ground. The grab is then closed by the derrick operator, and during the closing action the two cutting edges are drawn together with the whole weight of the bucket upon them, and this causes the soil to be scraped up and confined within the grab, when the latter is once again closed. The grab is then hoisted and the derrick jib is swung round to enable the contents to be discharged directly into a tip waggon or on to a spoil heap, as required ; this discharge taking place by the operator releasing the closing mechanism of the grab and allowing the sections to open out. This method is not suitable for very hard soils which offer considerable resistance to the grab when the bite is being made, but for all ordinary soils it is very economical. In the case of stiff clay or similar soil it is a good plan to use a trench digger to cut some trenches parallel with the length of the excava-

Fig. 4. Locomotive Crane and Grab.

tion before the grab is brought into operation, as this enables the teeth and edges of the grab to bite into the vertical faces of the solid portions which remain, and secure a full bite. Where the soil is difficult it is quite common practice to take a succession of small bites to loosen the ground and then pick up the whole of the loose material with one bite before hoisting the grab. Only two men are required by this method of excavation, viz. the derrick operator and the " watcher " or labourer, who directs the derrick man when to raise, lower and bite, and thus it is a good labour-saving scheme. Of course the results as regards speed will depend considerably on the skill of these two men in the handling of the grab to secure the maximum bite, which is often a matter requiring some judgment, but the necessary experience can quickly be acquired.

Fig. 5. Side View of a Steam Digger cutting a Drainage Trench.

The grab is frequently used in connection with a locomotive crane where a temporary track is laid down for general use during the construction of a building, and, apart from its use for actual excavation on its own account, the locomotive crane and grab will frequently prove a useful accessory for lifting the soil that is cut up with a steam shovel when the cutting is too deep to allow the latter to discharge the contents of the dipper at the original surface level. Such an example is illustrated in *Fig.* 4, where a large deep cutting is being formed. The small steam shovel cuts up the ground and piles up the loose dirt in front,

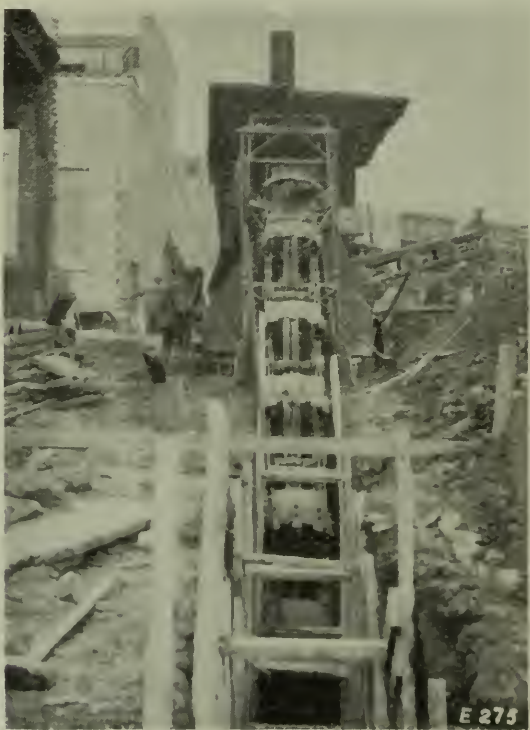


Fig. 6. Back View of a Digger.

Fig. 7. Steam Shovel excavating for Subway.

while the crane and grab worked from the original surface level continually grab up this loose soil, raise and load same into side-tip waggons on a narrow gauge track running parallel to the crane track and cutting. This is an expeditious method of excavation, and when a large amount of work has to be done the cost of the mechanical installation will soon be repaid.

Trench Diggers.—These are extensively used for excavating trenches for wall foundations and pipe lines, and generally speaking they are unequalled for all ordinary work as they produce a clear-cut trench at a low cost. Three illustrations are given of these machines in operation, *Fig.* 5 showing the side view of a steam-driven machine cutting a trench across an open site; *Fig.* 6 the back view of a digger, also steam driven, cutting a drainage trench close to buildings in course of erection, and *Fig.* 8 a petrol-driven machine excavating a trench for a water main at the side of a road. This type of machine consists of a travelling carriage, propelled by steam power or petrol engine, from which a movable steel arm extends

Fig. 8. A Petrol-Driven Machine excavating Trench for a Water Main.

at the back to support a conveyor belt on which are small shallow buckets fitted with teeth. This belt revolves to draw the teeth of the buckets in an inclined direction against the exposed face of the soil in the trench, causing the dirt to be scraped off into the buckets. On rising to the top of the belt the buckets discharge their contents automatically on to a second conveyor belt which runs at right angles to the trench, and which carries the soil either direct into a tip waggon or on to the ground adjoining the machine ready for back filling. The arm carrying the main belt is adjustable and it is set at an angle which will give the required depth to the trench. It has been found, however, that a maximum depth of 10 ft. is the limit of this method of excavation, because beyond this limit the efficiency of the machine rapidly diminishes, and it is not economical. For all depths up to 10 ft., however, this method is ideal, as any line or grade established by the field engineer can easily be followed, and considerable output can be obtained. The caterpillar wheels at the back of the machine where the load occurs enable same to travel over very soft ground, especially if some rough boards are used to increase the bearing on the soil, these being moved forward to the front of the machine as required.

Steam Shovels.—The steam shovel is the most important piece of plant used for all large excavation work, and although it has been adopted in this country to some extent it is not so generally employed as in America. In domestic work, where practically every house has a basement wherein the heating furnace is installed, a steam shovel is usually brought on to the site to make the excavation

Fig. 9. Steam Shovel and Horse-Drawn Wagon.

Fig. 10. Steam Shovel with Caterpillar Wheels.

for this as it has proved economical in addition to being expeditious, and therefore on a large scheme this piece of equipment is considered quite essential. The type of shovel employed will, of course, depend upon the conditions and nature of the work to be done, but in all cases the shovel consists of a carriage, attached to broad-rimmed or caterpillar wheels, on which the boiler, engine and boom are supported. The boom is attached to the carriage by a pin connection, which enables the operator to lower and raise same, and simultaneously to swing the whole in a full circle. The dipper or shovel operates on a long handle, which passes between the two halves of the boom, and this dipper functions by means of a cable taken over the pulley at the end of the boom, and thence to the winding drum of the engine. In operating, the dipper is drawn back toward the carriage, dropped down to the soil below, and then pushed forward by the handle travelling

Fig. 11. Steam Shovel and Locomotive Crane.

Fig. 12. Grading with Steam Shovel.

through the boom in such manner that the steel teeth on the dipper bite into the earth, and moving through an arc the dipper is raised gradually until a full shovel is obtained. It is then rapidly lifted and the whole carriage is swung around to bring the dipper over the point of deposit, when the contents are emptied by the operator pulling a cable to release the hinged bottom of the dipper. The soil is transported from the point of excavation by various means, and *Fig.* 9 shows a steam shovel engaged in a wide cutting depositing the excavated soil into a bottom-opening dump wagon drawn by horses. This shovel is a large capacity one with a short dipper handle adopted for comparatively shallow cuttings, and it is capable of removing 600 yds. cube per day under ordinary circumstances. The shovel in *Fig.* 10 is an example of one with caterpillar wheels, which are extremely useful for travelling over soft or hilly ground. The excavated soil is here shown as being removed in side-tip trucks drawn by a small locomotive or "dinkey" on a narrow-gauge track. The photograph was taken at the instant of discharge and the hinged bottom of the dipper is plainly shown. *Fig.* 7 is a good typical example of a steam shovel at work in a cutting which was being executed for a large pipe subway, and it will be noticed that the concreting operations are following closely behind the excavation. The use of the steam shovel in a deep cutting with a locomotive crane as an accessory for grabbing up the excavated soil is shown in *Fig.* 11. A rather unique illustration of the use of the steam shovel is that given in *Fig.* 12, where it is shown inside a building in the act of grading the

FIG. 13. STEAM SHOVEL EXCAVATING DRAINAGE TRENCH.

soil ready for the reception of the surface concrete. The shovel was required for foundation work of various kinds on this scheme and could not be spared for the grading work in the early stages of the scheme, but after the whole of the structure was erected it was brought inside the building and successfully removed the whole of the surplus soil at a very low cost as compared with hand labour. The height from the finished floor to the underside of the tie beams of the roof was only 14 ft., but this was found sufficient and the soil was picked up and deposited into side-tipping trucks running on a narrow-gauge track, which can be seen on the other side of the shovel.

The use of a steam shovel for cutting drainage trenches would appear unnecessary at first sight, but when applied to a deep trench in which large diameter pipes are to be laid, it will be found expeditious and economical. The type of shovel for this work needs to be one with a long dipper stick, with a small dipper at the end, and caterpillar wheels are not desirable. The shovel operates at the normal ground level, as shown in *Figs.* 13 and 14, immediately over the trench it is cutting, support being provided by several balk timbers arranged in convenient sections, which are picked up by a chain attached to the dipper and moved forward as required. The wheels of the shovel are securely blocked with pieces of wood to keep the machine from moving out of position while excavating. In the execution of the work by this method a length of trench is cut by the shovel and the large pipes—usually of reinforced concrete—are picked up by a chain attachment on the dipper stick and lowered into the trench behind the shovel. They are then adjusted to give an accurate fall and jointed in the usual manner. The back filling is also done with the shovel which excavates the soil in front as it proceeds along the trench, and swinging round through an arc of 180 degrees it deposits same in the trench behind wherein the pipes have been laid. This method has the advantages that only a short section of the trench is open at one time, the amount of surplus soil at the side of the trench is reduced to a minimum, thus avoiding considerable obstruction, it is economical, as the dig and backfill are achieved at one operation, and it effects a saving in time as compared with that of opening a long trench which is backfilled in a second operation.

Steam Shovel cutting Drainage Trench.

MEMORANDUM.

The American Concrete Institute.—The Annual Convention is to be held in Cleveland this year, February 13–16. There will be nine Convention sessions divided up as follows: Two for contractor problems, two for concrete products manufacturers, one session for roads, one for houses, one for research, and two for engineering design and inspection.

THE CONCRETE INSTITUTE.

MONTHLY NOTES.

By the SECRETARY.

THE ANNUAL DINNER.

His Majesty's Minister of Health, the Rt. Hon. Sir Alfred Mond, Bart., M.P., has accepted the invitation of the Council to be the Guest of the Concrete Institute at the Annual Dinner, to be held at the Savoy Hotel on Thursday, February 2nd, 1922.

Tickets are being printed, and early application should be made by members, in order to ensure obtaining them. Members may bring guests, including ladies, and should state when applying for tickets, or as soon as convenient, the names and titles of their guests for inclusion on the Table Plans, etc.

The price of single tickets is 15*s*., and of double tickets (for lady and gentleman only), 27*s*. 6*d*. each ; and application should be made to the Secretary of the Institute, Captain M. G. Kiddy, 296 Vauxhall Bridge Road, S.W.1.

COUNCIL APPOINTMENTS.

The Council has nominated Mr. H. J. Deane to fill a Vacancy for a Vice-President ; and to fill the position on the Council caused by Mr. Deane's elevation, they have co-opted Professor E. R. Matthews.

Major James Petrie has been elected Chairman of the Finance and General Purposes Committee, of which Mr. H. J. Deane has been elected Vice-Chairman. Votes of thanks have been accorded the outgoing Chairman and Vice-Chairman, Mr. Searles-Wood and Sir Henry Tanner.

Mr. B. Taylor has been co-opted a member of the Reinforced Concrete Practice Standing Committee.

JANUARY MEETING.

The 108th Ordinary General Meeting of the Concrete Institute will be held at Denison House, 296 Vauxhall Bridge Road, S.W.1, on Thursday, January 26th, 1922, at 7.30 p.m., when a paper, illustrated with lantern slides, will be delivered by Mr. E. B. Moullin, M.A., on " Capillary Canals in Concrete and the Percolation of Water through Them."

The President and Council invite the attendance of all members at this Meeting. Members may bring their friends, including ladies. Smoking is permitted and no tickets are required.

CONCRETE INSTITUTE EXAMINATION.

HELD OCTOBER 20TH AND 21ST.

The following candidates have successfully passed the Examination of the Concrete Institute— which was held on October 20th and 21st, 1921.

DACEY, George Ernest Cecil	Part I
STALKER, Albert William	Part II
TURNER, Ernest Charles	Parts I and II
MURGATROYD, Norman Brinton	Parts I and II

CONCRETE AGGREGATES.—*(continued)*.

Note.—The publication of these lists commenced in the August issue, 1920, and was continued in the issues for September, November, December, 1920, and in March, April, May, June, July, August, September and December, 1921.

The Concrete Institute takes no responsibility for the accuracy of the information supplied.

For footnote references, see September, 1920, issue.

Leeds.

(1) *General description* : Red brick and firebrick crushed and screened as required.
(2) *How obtained* : Locally.
(3) *Is available quantity limited?* A large quantity available.
(4) *Present maximum output per day* (*in cubic yards*) : About 25 cub. yds.
(5) *Transport facilities* : Road, canal, or rail.
(6) *Provision at or near source for washing or crushing?* At the Works of Messrs. Wm. Simpkiss, Swan Junction, Hunslet, Leeds.
(7) *Price per cubic yard, and where delivered* : 6*s*. at above works, 10*s*. on boat or truck.
(8) *Is composition uniform?* Fairly.
(9) *Shape of particles* : Angular.
(10) *Size of particles ; approximate percentage that needs crushing to pass ¾-in. screen* : 3 in. downward to sand.
(11) *Impurities present* : Small percentage of old lime or fireclay in sand.
(12) *Weight per cubic foot, dry* : About 17 cwts. per cubic yard.
(13) *General remarks* : Approved by Technical Department, Leeds University.

Leicestershire.

(1) *General description* : Broken stone.
(2) *Source and locality of same* : Bardon Hill Granite Quarries.
(3) *How obtained* : By quarrying, and through breaking plant.
(4) *From whom obtained* : Ellis & Everard, Bardon Hill, nr. Leicester.
(5) *Is available quantity limited?* Quantity limited by possible output, present demand and shortage of labour.
(6) *Present maximum output per day* : About 350 tons of all sizes.
(7) *Transport facilities* : Railway.
(8) *Provision at or near source for washing or crushing?* All stone is broken and graded, and a portion of gravel is washed.
(9) *Price per cubic yard, and where delivered* : About 9*s*. to 14*s*. per ton (according to size) f.o.r.
(10) *Is composition uniform?* Yes.
(11) *Detailed description* :—
- (*a*) *Kind of stone or coarse material* : Broken granite.
- (*b*) *Kind of sand or fine material* : Gravel and dust from stone breakers.
- (*c*) *Relative proportions of coarse and fine material* : About 75 per cent. above ¾ in. About 25 per cent. ¾ in. and under.
- (*d*) *Shape of particles* : Angular.
- (*e*) *Size of particles : approximate percentage that needs crushing to pass ¾ in. screen* : All sizes supplied from 2¾ in. down to dust. See (*c*).
- (*f*) *Impurities present* : None.

(12) *Specific gravity* : 2·80.
(13) *Weight per cubic ft. dry* : 90 to 95 lb. according to size.
(14) *Crushing strength of stone* : 43,578 lb. per square inch.
(15) *Absorption of stone, as percentage by weight* : None.
(16) *Proportion of muddy matter* : Only a little fine dust. No mud

REINFORCED CONCRETE AND FIRE RISKS.

(Contributed.)

The assessment of the fire risks appertaining to various methods of construction must necessarily be based largely on experience, and as such experience in the large range that is desirable is generally not obtained for several years after any new constructional system has been introduced, it follows that there is a tendency for the ideas on which fire risks are assessed to be somewhat out of date. Under these circumstances, the tests of the fire resistance of various systems of construction carried out by the British Fire Prevention Committee, the United States Bureau of Standards and others, are of considerable importance and need to be strongly emphasised if the results of such tests show that current ideas of fire risk surveyors are not in line with reasonable deductions from the experiments.

While it is a thankless task for one who is outside the fire insurance profession to suggest that its authorities are not up-to-date, it is nevertheless the duty of the "concrete man" with an intimate knowledge of his own material to urge unceasingly the claims of fire resistance which can be substantiated by well-authenticated experiments, and not to rest until he is assured that concrete has been assigned its proper superior position as a fire resistant.

It may, perhaps, be suggested by the fire surveyor that actual experience of reinforced concrete under fire is not lacking, and that the exalted position claimed by the concrete enthusiast is not justified, but if this be granted, the fact still remains that such experience is not connected with modern concrete in which the lessons learned from early failures have been applied. It is quite possible that concrete buildings exist which cannot be considered good fire risks on account of inadequate protection of reinforcement by concrete, or the use of aggregate which readily splinters with heat or for other reasons, but the present-day concrete engineer who aims at fire resistance knows of these weaknesses and avoids them, and is consequently warranted in protesting against all concrete buildings being judged on the basis of early examples.

British fire insurance offices appear to have adopted a system of rebates in premiums to coincide with certain reductions in the fire risk, the allowances ranging from 10 per cent. to 40 per cent. under four standards, but so far as the building construction is concerned, the allowance is the same so long as structural metal is protected by bricks, terra-cotta, concrete, etc., practically the only distinction being between an unprotected steel structure—for which no rebate is made—and protected steel structures, which include reinforced concrete. The chief considerations which govern the inclusion of a building in any one of the four standards mentioned—apart, of course, from the nature of the contents, which is of prime importance—are dimensions, openings, flues, etc., and material of construction is regarded as of lesser importance. In connection with these considerations, those who are not fire experts cannot express an opinion, but there is certainly ground for complaint that modern reinforced concrete buildings are not given decidedly preferential rates for insurance purposes.

The evidence in support of this dissatisfaction must be presented, and it may be permissible to theorise before stating facts. Consider, then, a reinforced concrete building in which the reinforcement is everywhere protected by 2 in.

of concrete and where the aggregate in the latter is an igneous rock not liable to spalling. The low heat-conductivity of concrete serves to protect the steel from damage by heat and the aggregate is not liable to disintegration or fusion upon the application of heat ; moreover, the building derives its strength from the association of concrete and steel. Hence, such a structure is surely entitled to a higher classification than one where the protecting material has a higher conductivity than concrete and does not possess the strength of concrete, and where the removal of only a portion of the protecting material would expose the steel work to the action of fire and so endanger collapse.

Turning to experimental evidence, the most recent available is to be seen in a publication of the United States Bureau of Standards (Technologic Paper No. 184) where are given results of fire tests of 106 building columns conducted at the Underwriters' Laboratory in conjunction with Fire Insurance Companies and Fire Underwriters. Among the four classes of columns tested were (1) reinforced concrete and (2) steel protected by 2 in. or 4 in. of concrete, hollow tile, brick, etc., and the results should accordingly refute or confirm the belief that fire insurance surveyors would be justified in allowing a rebate in premium for buildings of class (1) compared with those of class (2).

The reinforced concrete columns tested were 12 ft. 8 in. long by 16 in. square or 17 in. diameter, the concrete being 1 : 2 : 4 and containing various aggregates. The reinforcement was of the usual types and the columns were designed for a working load of 100,000 lb. During the tests the columns were subjected to a constant working load and the temperature was regulated to reach 1,700° F. at one hour, 2,000° F. at 4 hours, and 2,300° F. at 8 hours.

The results demonstrate that reinforced concrete columns were the most fire resistant, and showed a marked superiority in this respect to protected steel columns, as will be seen from the following tabulation :—

	Time at which failure occurred.
Reinforced concrete	7 hrs. 23 mins. to 8 hrs. 40 mins.
Steel with brick protection	1 hr. 40 mins. to 7 hrs. 13 mins.
,, ,, hollow tile protection	50 mins. to 4 hrs. 42 mins.
,, ,, concrete protection	1 hr. 47 mins. to 8 hrs. 24 mins.

The superiority of concrete as a fire resistant is exemplified not only by the reinforced columns, but also by the protected columns where concrete gives better results than other protecting materials. The paper in question gives many tests of other columns such as timber, unprotected steel, cast iron, etc., and the results confirm the wisdom of placing such constructional materials in an entirely different class to concrete and protected steel.

In view of the impartial status of the investigators and the extreme thoroughness of their work, the conclusions to be drawn from the tests quoted are entitled to be regarded as authoritative, and if fire surveyors can be persuaded to be influenced by experimental work, a preferential tariff for reinforced concrete constructions should at once materialise. Fire insurance experts may well argue that all reinforced concrete is not alike from their particular point of view, and this is readily admitted, and if need be the " concrete man " would be content if the desired preferential tariff applied only to concrete work with say non-spalling aggregate, adequate cover of reinforcement with concrete, and other features which experience has shown to be desirable. Additional experimental evidence upon the subject of the fire resistance of reinforced concrete is to be found in the summary of the British Fire Prevention Committee's tests published in recent numbers of this journal.

A further and most valuable piece of evidence upon the subject is given by the British Fire Prevention Committee's Red Book No. 207, showing the results of the investigation following the fire at the Edison Phonograph Works at New Jersey, U.S.A., where a number of large reinforced concrete buildings were involved. In this publication, the following extract is given from a report upon the fire by the Associated Factory Mutual Fire Insurance Companies of America—a body which represents the interests of the building owner and quite impartial as to constructional materials :—

"This fire shows that a reinforced concrete building is a fairly good furnace or stove, for these buildings withstood the complete burning out of a large amount of combustible contents with only such damage to the buildings themselves as can be repaired at reasonable cost."

The severity of the fire is demonstrated by the fact that fused iron, copper, brass and glass were found in the concrete buildings after the fire, and it was considered that temperatures in excess of 2,500° F. were reached. The following extracts from the Red Book are quoted :—

"In general, under ordinary conditions of fire exposure, the concrete, while cracked, was not damaged to any great extent.

"The end walls in the three upper floors . . . were of reinforced concrete 8 in. thick . . . while this was in the hottest part of the fire, these walls were practically undamaged, and are an admirable demonstration of the value of concrete walls as a fire barrier.

"In the greatest portion of these buildings the concrete remained firm and hard and intact after this severe heat treatment.

"While the surface indications were that the strength of the floor construction had been severely damaged by the fire, the factor of safety assumed in the design was sufficient to meet the unusual fire test, and the floors before repairs had sufficient strength to carry, for a time at least, the designed live load, although the use of the building and the effect of moving machinery might have later reduced the strength if repairs had not been made.

"The salvage in machinery in the reinforced concrete buildings is at least 94 per cent. ; of the buildings 87 per cent., and the cost for the restoration of the buildings from 10 to 15 per cent."

Theory, experiment and practice all combine to support the contention that reinforced concrete is the best fire resistant material for modern structures, and it is in the interests of all concerned that this type of building should be encouraged by insurance companies by granting a preferential tariff.

THE PROTECTION OF CONCRETE STRUCTURES AGAINST CHANGES IN TEMPERATURE.

Investigations by Henky and Knobloch of Munich show that the thermal conductivity of slag concrete is only 0·16 calories for a temperature difference of 1 deg. Centigrade in a wall 3 ft. 4 in. thick. The corresponding figure for brickwork is 0·35 calories, but for wet bricks it rises to 0·61 calories or even more. Consequently the resistance of slag concrete to the leakage of heat is more than double that of brickwork, and may be five times as great. Investigations made at the State testing station at Berlin-Dahlem show a similar result.

The stability of concrete in a conflagration is well known and has been proved by many fires.—*Zement.*

THE FIRE RESISTANCE OF CONCRETE AND REINFORCED CONCRETE.—(*Concluded.*)

The following is the concluding portion of an abstract from a paper read by Mr. D. W. Wood before the Junior Institution of Engineers and summarises the details and results of tests carried out by the British Fire Prevention Committee under a grant made by the Scientific and Industrial Research Department—Ed.

Conductivity Tests.*

Many of the various aggregates were made up into cement concrete slabs on the same lines as the concretes for the plain and reinforced concrete slabs for the fire tests. They were 40 in. by 40 in. and 5½ in. thick. During their construction thermo-couples were inserted in each slab at points ¼ in., ½ in., 1 in., 2 in. and 5¼ in. respectively above the soffits. These were inserted in duplicate, and as there was a possibility of the junctions becoming displaced during tamping their positions were re-determined by cutting into the slabs after the tests. The temperature of the fire for the test was gradually to reach 1,800° F. but not to exceed 2,000° F., and the test was to last four hours. No water was to be applied at the close. Dealing with one series of thirty slabs, the following particulars are of interest :—

The lower layer of reinforcement (if it had been used) with 1 in. cover would have attained 1,300°F. in ten cases:—Pit ballast, Dowlais slag,† coke breeze and sand, clinker, pan breeze and fine pan breeze, Shap granite, Darley Dale millstone grit, York sandstone, Nuneaton granite and Thames ballast; whilst the temperature of the upper layer of the reinforcement would be about 200°F. less.

In only eight cases would the temperature have failed to reach 1,200 F. at the level of the lower layer of the reinforcement, viz—Middlesbro' slag, Buxton limestone, Portland limestone,† Nottingham basalt, Irish andesite,† fine coke breeze, broken stock brick (Langley) and whinstone.†

If only ½ in. cover had been used all the concretes would have allowed the temperature at the lower layer of reinforcement to attain 1,200°F. during the four hours, and only Dowlais slag would have prevented this during the first two hours.

In five cases the temperature at the point nearest the top exceeded 212 F., viz — Thames ballast (2), Irish pit pebble,† coke breeze and Nuneaton granite.

The following is a list of the Red Books upon which the above Paper was prepared—

Plain Concrete Slabs.		*Reinforced Concrete Slabs.*		*Conductivity Slabs and General Reports.*	
C. 1/12	R.B. 212	R.C. 1/2	R.B. 221		
13/20	213	3/6	222	C.C. 1/30	R.B. 251
21/32	216	7/10	223	31/54	252
33/40	217	11/14	226	Mechanical Tests	257
41/46	218	15/18	227	Geological particulars	256
47/54	219	19/22	229		
55/62	224	19R, 23, 25, 26	231		
63/68	228	24, 27, 29, 30	232		
69/76	237	24R, 27R, 28, 35	234		
77/84	243	31/34	238		
85/92	249	3X, 4X, 34R, 44	239		
		7X, 13X, 15X, 36	242		
		12X, 37, 38, 42	244		
		39, 40, 41, 43	246		
		19X, 23X, 24X, 25X	248		
		11X, 16X, 26X, 46	250		

* Based on Dr. Lees' Red Book, No. 251.

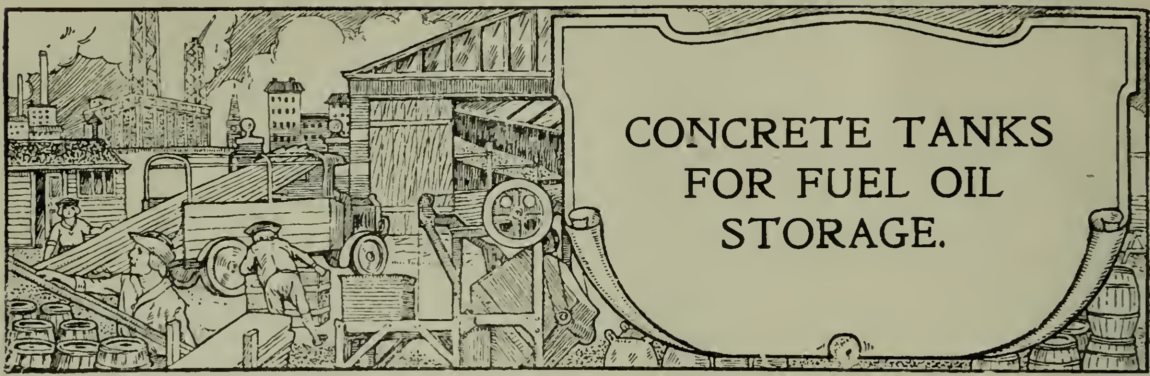
† Not tested in Reinforced Concrete

Tabulated Results of the Tests on Reinforced Concrete.

There were 26 + 1 = 27 different aggregates tested and these can be classified as follows :—

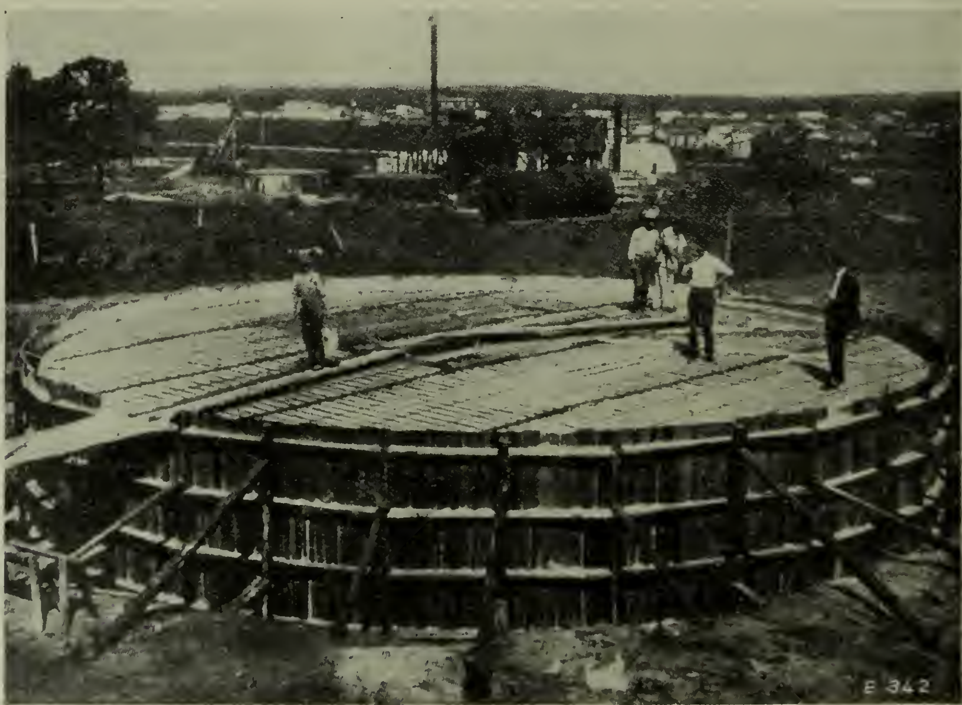
	No. R.C.	Red Book.	Perm. Defln. Inches.	Order.	Collapsed in Minutes	Temp. reached °F.	Order.	Fine other than Sand, Proportion other than 4 2 1.	Cover Inch.	Protection, Thickness Material and Proportions.	Remarks.	Reference to— Plain Concrete Slabs.	Reference to— Conductivity Slabs.
NATURAL :													
2. GRAVELS—													
Thames Ballast .	3	222			193	1870	16		½			C 1 etc.	CC 1
,, .	3x	239			220	1860	20		½		12 mths. old	,,	,,
,, .	4	222	9	31					1½			,,	,,
,, .	4x	239	10½	35					1½		12 mths. old	,,	,,
,, .	7	223	11⅝	37					1			,,	,,
,, .	7x	242	15	38					1		12 mths. old	,,	,,
,, .	10	223	11	36					1		Load 280 lb.	,,	,,
. .	12	226			234	2000	22		½	1 in. Coke Breeze 5·1		C 18 etc.	CC 2
,, .	12x	244	2¾	9					½	1 in. Coke Breeze 5·1	12 mths. old	,,	,,
,, .	22	229	3⅜	14					½	1 in. Coke Breeze 5·1		,,	,,
.. .	26	231	9¼	32					½	1 in Pan Breeze 5·1		C 66	CC 17
,, .	26x	250	5¼	22					½	1 in. Pan Breeze 5·1	12 mths. old	C 66	,,
,, .	37	244			110	1680	4		½	1 in. Coke Breeze		C 18 etc.	CC 2
,, .	38	244			92	1760	2		½	1 in. Brick 5·1		C 68	
Thames Ballast and Nottingham Basalt	42	244	9½	34	—	—	—	—	1 —	—	Thames Ballast 2 Nottingham Basalt 2	C 84	
Tame Gravel .	6	222			184	1880	12		½				
4. SANDSTONES—													
Nuneaton Granite	5	222			168	1840	10	Nuneaton Granite 6 1	½			C 41 43 62 C 44	CC 15
Bargate Stone .	31	238			88	1600	1		1			C 75	
Kentish Rag .	41	246			169	1750	11		1			C 80	
Millstone Grit—													
Darley Dale . .	21	229	5⅞	24					1			C 55	CC 13
2. LIMESTONES —													
Buxton . . .	25	231	7	28					1			C 69	CC 25
,, . . .	25x	248	4	17					1		12 mths. old	,,	,,
Stoneycombe (Devonshire) .	40	246	4	17					1			C 77	
7. IGNEOUS ROCKS													
Nottingham Basalt (Bonsall Wood Stone) . . .	17	227	3¼	13	—	—	—	—	1	—		C 57	CC 26
Do. and Thames Ballast . .	42	244	9½	34	—	—	—	—	1	—	Thames Ballast 2 Nottingham Basalt 2	C 84	

Rowley Regis Granite (Dolerite) .	17	227	6¾	27					1			C 56	
Trachyte . . .	19	229	2⅞	10					1			C 70	CC 11
"	19R	231	+2	20					1		Repaired and re-tested		
" . . .	19x	248	3¾	16					1		12 mths. old	" C 70	" CC 11
Shap Granite . .	23	231			198	1860	17		1			C 71	CC 10
" . .	23x	248	7⅞	30					1		12 mths. old		"
Troon Stone . .	28	234			184	1870	12		1			" C 73	
Teign Granite (Diabase)	32	238			96	1540	3		1			C 79	
"	39	246	5	21					1				
Meldon Granite .	43	246	6⅜	25					1			" C 78	
ARTIFICIAL :													
3. Clinker—													
Lots Road . . .	1	221	3	11					1			C 24 etc.	CC 7
Comml. Gas Co. .	36	242			205	1900	19		1			C 81	
Mond Anthracite .	46	250	2½	6					1			C 86	
1. Slag . . .	20	229	6⅝	25					1			C 76	CC 23
2 Pan Breeze—													
South Met. Gas, Old Kent Road	15	227			155	1810	8	Pan Breeze 3 2 1	1			C 82	CC 8
"	15x	242			122	1610	5	Pan Breeze 3 2 1	1		12 mths old	"	
South Met. Gas, Vauxhall	29	232			191	1900	15	Pan Breeze 5 1	1				
"	30	232			132	1640	6	Sand 3 2 1	1				
2. Coke Breeze—													
Gas Light & Coke Co. . . .	2	221			186	1860	14	Coke Breeze 4 2 1	1			C 49	Cp. CC. 3
South Met. Gas, Vauxhall	13	226	3½	15				Coke Breeze 2 3 1	1				CC 30
"	13x	242			230	1970	21	Coke Breeze 2 3 1	1		12 mths. old		" CC 3
"	14	226			236	1990	23	Coke Breeze 4 2 1	2				Cp. CC 29
"	16	227	7¼	29				Sand 3 2 1	1				
"	16x	250	4	17				Sand 3 2 1	1		12 mths. old		"
3. Brick, etc.													
Stock Brick (Broad)	8	223			236	1930	23		½			C 33 etc	Cp. CC 9
"	9	223	3⅛	12					1		Load 280 lb.	"	
"	11	226	9¼	32					½	+ 1 Coke Breeze		C 38	
"	11x	250	1¼	1					⅓	+ 1 Coke Breeze	12 mths. old	C 38	
,,(Langley)	24	232	2	4					1				CC 9
"	24R	231	+½	6					1		Repaired and re-tested		
"	24x	248	5¼	22					1		12 mths. old		"
"	27	232	1½	2					1½				"
"	27R	231	+¾	5					1½		Repaired and re-tested		"
"	35	231			200	1870	18	Coke Breeze 4 2 1	1				" CC 28
Gault Clay . .	33	238			160	1750	9		1			C 74	
"	34	238	1¼	2				Gault Clay 4 2 1				C 83	
"	34R	239	+1⅛	8				Gault Clay 4 2 1	1		Repaired and re-tested		
.	44	239			148	1750	7		1			" C 74	



CONCRETE TANKS FOR FUEL OIL STORAGE.

It is common knowledge that during recent years oil as a fuel has been more widely adopted and its value more fully appreciated, and in many directions we find that where coal has hitherto been employed oil is now taking its place. Without entering into the question of the relative merits of oil and coal as fuel—a question which does not come within our province—the fact remains that oil is being used for this purpose to an increasing extent, and this brings us to the question of storage, which is an important one.



Building a Concrete Tank for the Storage of Light Crude Oil.

For the successful storage of oil, the containers must, among other things, prevent loss by seepage and evaporation and must afford the greatest protection against fire, the latter being one of the most urgent problems associated with the storage of this form of fuel, since an oil fire is one of the most difficult fires to extinguish.

These requirements are found to be met most completely by concrete. The employment of concrete for this purpose is by no means new. In the United States concrete tanks and reservoirs have been successfully used for storing oil for some seventeen years, and the experience extending over that period has shown that there are many advantages in underground storage, the tanks being so constructed that they can be roofed and afterwards covered with a foot or two of earth. One advantage of this method is that, on account of the insulating properties of concrete, the oils are maintained at a more even temperature, so that loss through evaporation is reduced to a minimum; and, in extremely cold weather they will not become congealed and so rendered difficult to draw off.

Another advantage, and one of inestimable value, in the use of concrete is the reduction of fire risk, since concrete does not attract lightning and is fire-resisting, and if the top of the tank is a foot or two underground the protection of the contents from ignition is as great as possible. Indeed, with underground concrete construction there is practically only one way whereby the oil can take fire, and that is through the gases escaping from the vent; but even this risk is now rendered insignificant by the production of a special type of vent, patented in the United States and installed in a number of systems.

A further advantage offered by concrete is that it does not rust or rot and thereby large sums are saved in maintenance; in fact well-made concrete increases in strength over a long period.

Newly-completed Concrete Fuel-oil Tank.

A Bulletin on this subject (No. 155) issued in 1918 by the Bureau of Mines, U.S. Dept. of the Interior, contains some very interesting reading. Referring to the storage of low gravity oil, this bulletin says:

" Where proper care has been taken to make a dense compact lining in which all coarse material is embedded below the surface, there seems no doubt that an oil-tight structure can be made. The writer has repeatedly seen samples of concrete lining taken from the bottoms of reservoirs 20 ft. in depth which have been in use for a period of five years. These have shown practically no penetration whatever. Mr. H. B. Truett, chief engineer of the fuel-oil department of the Southern Pacific Railroad, states that he examined a 750,000-barrel reservoir belonging to the Company after it had been in continuous use for several years and found the concrete lining in practically perfect condition.

" In connection with the use of underground concrete tanks for the storage of oil, it is interesting to note that the El Paso and South-Western Railroad Co., at various places along its system, has for the past five years been storing fuel-oil of

24° to 38° B. in circular concrete tanks about 12 ft. in diameter by 6 ft. deep. The bottoms of these tanks are 8 in. thick and the sides 6 in. thick, and each tank is covered by a concrete roof.

"Tanks that have been in use five years have been examined inside and out, but no signs of leakage were discovered. At present the Company has twelve such tanks, and their adaptability to oil storage has proved so satisfactory that more are in process of construction. No oil or water-proofing compounds are used."

Needless to say, a concrete tank for oil storage must be carefully designed in order to withstand the pressure of the liquid, but given a suitable design the rest depends upon the use of high-grade material and good workmanship. The cement should be British made and should satisfy the British Standard Specification. The aggregate should be carefully selected, and the proportions such that the densest concrete is produced. In all cases the best proportion should be ascertained by previous experiment with the materials actually to be employed on the job. The mixing should

INTERIOR VIEW OF 150,000-GALLON CONCRETE OIL TANK.

be thorough and uniform and preferably done in a batch mixer. Where possible, arrangements should be made for the operation of concreting to be carried out from beginning to end without intermission, by which means all construction joints are avoided. Where, however, this is not practicable, the work should be speeded up, as much as possible, in order to reduce the number of such joints to a minimum, and special steps must be taken in order that after a suspension of the work a good bond is produced between the new concrete and that previously laid.

It is important that freshly laid concrete should not be allowed to dry out quickly. In order that it may attain its maximum strength the work should be protected from the rays of the sun and from drying winds by being covered with sacking or other suitable material and kept wet for several days.

In cold weather the aggregate and the water should be heated and the concrete protected from freezing until it has properly set.

As soon as the concrete is sufficiently hard to withstand the pressure it is a good plan to fill the tank with water, which materially assists the curing. The water should be kept in the tank for at least three weeks.

By the courtesy of the Portland Cement Association, U.S.A., we are able to give a few examples from a very informing tabular statement which summarises the results of a recent investigation of some 481 concrete tanks for oil storage.

Name of Company.	No. of Tanks.	Capacity, Gallons.	Year Built.	Gravity of Oil, Baumé.	Remarks.
Tonopah Mining Co.	1	145,000	1907	14°–16°	Satisfactory. No special treatment.
Shawnee Gas & Electric Co.	1	25,000	1909	26°–28°	Satisfactory. No special surface treatment
Associated Oil Co.	11	337,000,000	1910–1911	14°–16°	Satisfactory. Neat cement grout.
Standard Oil Co.	1	20,000,000	1916	15°–22°	Satisfactory. Neat cement wash
Yale & Towne Mfg. Co.	1	112,000	1918	35°–68°	Satisfactory. Special surface treatment.
Symington-Chicago Corp.	1	1,500,000	1918	—	Satisfactory. No special surface treatment.
Mt. Vernon Car Mfg. Co.	1	50,000	1918	25°	Satisfactory. One coat sodium silicate.
Mason City Oil & Grease Co.	2	10,000	1918	30°	Satisfactory. 2 ft. above ground Neat cement coating

From this it will be noted that while in some cases a special surface treatment has been adopted, in others the tanks are quite satisfactory with no surface treatment whatever, or with no other than a cement wash.

In our next issue we hope to publish a Model Specification for the Construction of Tanks.

MEMORANDA.

Corrosion of Water Mains.—In a paper recently read on this subject at the Conference of of the British Waterworks Association held in connection with the Public Works, Roads and Transport Congress, Mr. W. Ransom, city surveyor of Worcester, said he was in favour of a suitable coating to the mains to prevent corrosion. In the discussion which followed, Mr. F. W. Macaulay stated that he had lined 60-in. mains with concrete by a centrifugal process with satisfactory results. It is more than probable that the cement-lined pipe and the reinforced concrete pipe will supersede the cast-iron and steel pipe in a great measure. It is true that we still look to the chemist and metallurgist to produce metal of non-corrosive character suitable for pipes ; or to treat pipes in such a manner as to make the skin of the pipe non-corrosive. This has not been done yet. Recent evidence is generally to the effect that a cement lining is likely to be the best coating or protective measure in the future, but it is also quite possible that some new process, such as the " Delavaud " (in which the metal is met by centrifugal action) will produce a pipe in which the corrosion is negligible, or that the reinforced concrete pipe will prove to be so cheap and so satisfactory that it will supersede the metal pipe ; but whatever is done, it is unlikely that any one method will suit all cases. The engineer will always have to deal with conditions which need careful and special consideration, and every known method for the prevention of corrosion must be kept in mind.

Large Reservoir at Oxley, nr. Watford.—Work is to be started almost immediately on a 2,000,000 gallon reinforced concrete reservoir near Oxley. The contractors are Messrs. P. & W. Anderson.

THE ARTISTIC SIDE OF CONCRETE.

Now that concrete has established itself so firmly as a constructional material, attention is being turned in an increasing degree to its artistic possibilities, of which the vast majority of people have no idea whatever, regarding it only as a grey stone-like substance, useful for foundations, roads, paving slabs, floors and so forth.

The principal objections to concrete from the architectural standpoint have been its lifeless colour, its monotonous appearance, and the limited scope which it offers for variety and beauty of form. These objections, however, are not really justified, since they are based on limited experience.

Fig. 1. Concrete Headstone.

The architectural side of this subject does not come within the scope of this article, but our readers will remember that many very fine examples of concrete buildings, both large and small, have from time to time been illustrated in the pages of this journal, all going to show that in the hands of a capable designer, possessed of imagination, concrete can be treated, architecturally, as successfully as any other structural material.

Next to the general design of a building, its most noticeable features are colour and texture. Here, again, concrete presents a wide field for effort in the direction of surface treatment, since it contains within itself the elements for the production of rich and beautiful effects. These may be secured by various means—scrubbing the surface and so exposing the aggregate, tooling, sand-blasting or the absorptive method. Some very fine effects have been produced by the last-named, by the use of solutions of certain metallic salts. This method was adopted in the decoration of the concrete interior depicted in *Fig.* 2.

Apart from the building itself there are many ways in which the "home beautiful" may be rendered still more beautiful by the judicious use of concrete. Since the chief characteristic of this material is plasticity, it may be moulded to any shape; and since its colour depends upon the substances of which it is composed, by a careful selection of the aggregate, both coarse and fine, such a shade may be secured as will harmonise most completely with its surroundings. Balustrading, of which two examples are given in *Figs.* 3 and 4, is very effective

FIG. 2. A CONCRETE INTERIOR.

when carried out in concrete. In *Fig.* 3 the texture of the material, which has received a simple surface dressing, may be clearly perceived.

Concrete is also a useful material for the making of garden seats, which may take the form either of the simple bench as seen in *Fig.* 4, or the more ornate seat shown in *Fig.* 5. There is nothing in either of these seats that cannot be done by simple moulding. Products, however, of a highly ornamental character involving undercutting can, as a rule, only be fashioned by experts who possess special equipment, and in such cases it is generally better for the articles to be purchased ready-made from the specialist than that the amateur should attempt to make them himself.

Vases in concrete form a very decorative adjunct to a garden. Simple forms of garden vase are seen in *Fig.* 4, a more elaborate one with pedestal in *Fig.* 6, and a highly decorated vase in the illustration at the end of the article.

Window boxes, again, are in such common use, and when made of wood so

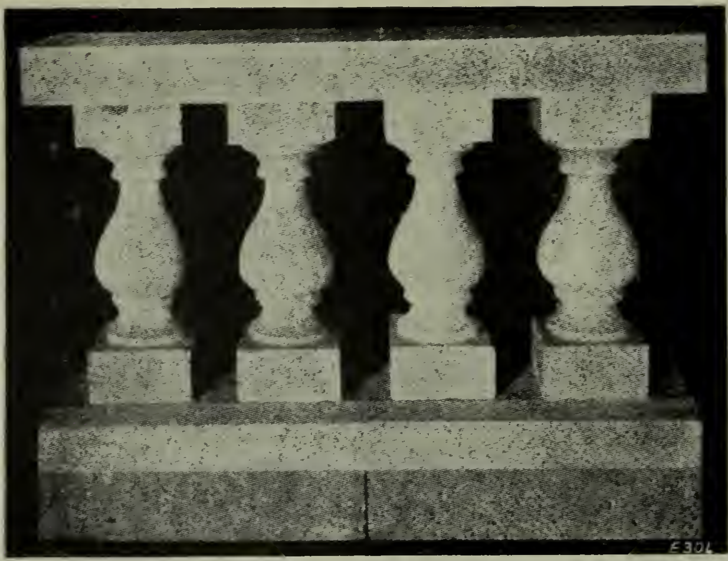


FIG. 3. CONCRETE BALUSTRADING WITH DRESSED SURFACE.

FIG. 4. CONCRETE BALUSTRADE, VASES AND BENCH.

FIG. 5. CONCRETE GARDEN SEAT.

quickly decay, that it is surprising that concrete, which is indestructible, has not been more widely used for the purpose, especially in view of the fact that it may be made porous in order to meet the requirements of receptacles for soil and plants. Such window boxes may range from the plain or panelled rectangular form to the decorated sample shown at the head of these notes.

Lamp standards are often required in the house and about the grounds.

FIG. 6. CONCRETE VASE AND PEDESTAL.

That illustrated in *Fig.* 8 is 8½ ft. high, and is only presented as a suggestion of what might be done in this way.

In addition to those mentioned above there are many other ways in which concrete may be employed for outdoor ornamental work, for which it is especially suitable since it is hard and durable, unaffected by atmospheric changes, and may, if desired, be coloured to almost any shade. The following are among the other uses to which concrete has been applied for the decoration of the garden :—Crazy pattern and other footpaths, edging tiles, pergolas, sundials, artificial ponds and bird baths.

Public authorities are gradually realising the artistic possibilities of concrete in many directions. We illustrate here, in *Figs.* 7 and 9, two electric light standards. (We may mention in parenthesis that many of the railway companies in this

Fig. 7. Concrete Lamp Standard.

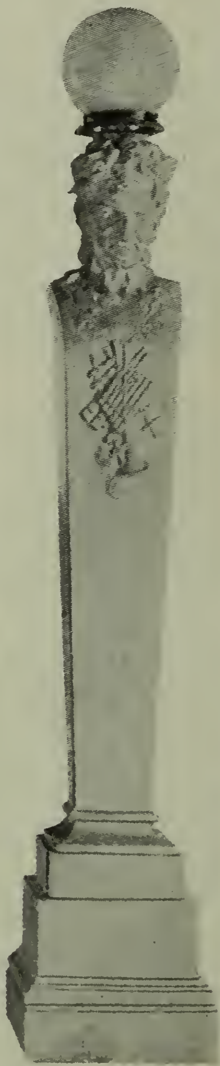


Fig. 8. Concrete Lamp Standard.

Fig. 9. Concrete Lamp Standard for Gas or Electric Light.

country are now replacing their wooden telegraph and signal poles, and their iron lamp-posts, by those of concrete. This should be a sufficient testimonial to their efficiency.) Then again our public parks are in most cases provided with fountains, an artistic example of which will be seen in *Fig.* 11. Other uses in the public interest, in which artistic effort may be brought into play are—horse-troughs, direction posts and other road signs, and street name plates.

The use of concrete for memorial stones has attained a considerable popularity in some parts of the Continent, Shell limestone constitutes the chief portion of the aggregate as such stones should, for the sake of appearance, have a light uniform colour. *Fig.* 1 shows a very simple form of headstone, and *Fig.* 10 a mausoleum.

FIG. 10.
CONCRETE MAUSOLEUM IN HANOVER.

FIG. 11.
FOUNTAIN OF SHELL LIMESTONE CONCRETE.

During the past few years a large number of firms, realising the value of concrete as a constructional material, have laid down plant for the manufacture of various products of a utilitarian nature. The artistic possibilities of concrete briefly indicated above, clearly point to another avenue but little explored in this country, and along which much useful work could be carried out. This would go far to remove the false impression that concrete can only be dull and monotonous.

For our illustrations we are indebted to the Patent Victoria Stone Co., Ltd., the Hall Concrete Products Co. Inc. (of America), the Concrete Utilities Bureau, the Società Cementi Armati Centrifugati (of Italy), and our contemporary *Zement*.

MEMORANDA.

Clean Concrete with Burning Gasoline.—Under " Hints for the Contractor," in a recent number of *Engineering News Record*, we read the following :—"Gasoline poured over asphalt joints between concrete slabs or on concrete surfaces and then ignited constitutes a method of cleaning the surface that is quick, inexpensive and does not damage the concrete, according to the Waterproof Paint Co. of Lankershim, Cal. A convenient way of removing the coating is to use a small oil can filled with gasoline. Several applications may be required to entirely remove all the old asphalt compound, the operator walking along the joints, each time leaving a trail of gasoline, which is then ignited. It is better to use a small quantity of gasoline and repeat the process, rather than to use a larger volume which might be dangerous in inexperienced hands. Where the method is used in concrete reservoirs covered with wooden roofs, care should be exercised to see that adequate ventilation is provided before the gasoline is used. The work can be done in sections, starting fires with small quantities of gasoline and returning later to re-burn where necessary. Working in this manner one man can ordinarily clear the surface quicker than a dozen labourers employed in scraping off the compound."

Dangerous Industries.—Some draft regulations under this heading have recently been issued by the Home Office, which especially affect the building industry as a whole. They deal mainly with scaffolding, ladders, cranes, hoisting apparatus, etc. Copies of the regulations as drafted can be obtained from the Home Office.

THE EXTERIOR APPEARANCE OF REINFORCED CONCRETE BUILDINGS.

By V. ELMONT, B.Sc., M.I.Mech.E.

AMONGST the multitude of reinforced concrete buildings which have been erected during the last twenty-five years a very considerable number show façades which clearly indicate the efforts of the designers to force this relatively new material into the garbs of the older ones, especially stone, brick and wood. The result is, as a rule, most unsatisfactory, a natural consequence of the fact that the structural properties of reinforced concrete are so entirely different from those of the other materials! With the compression strength of stone it combines the tensile resistance of steel, and as regards the technique of the material it bears no similarity to either brick or stone, as it is cast in wooden moulds.

Taking it as a maxim that a pleasing appearance of a building cannot be obtained without a clear expression in the exterior of the nature of the material

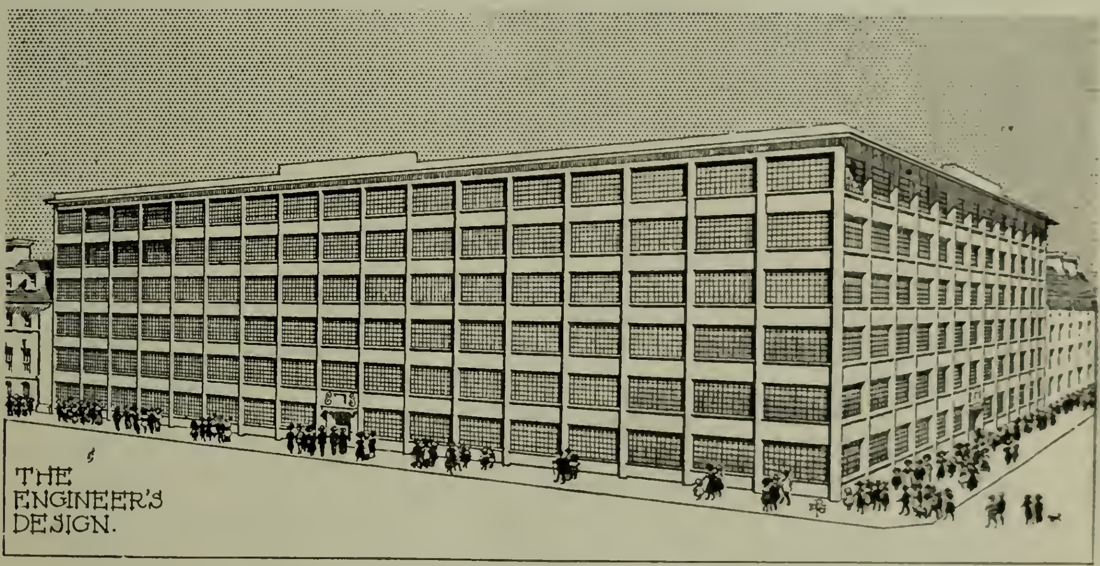


FIG. 1. THE ENGINEER'S DESIGN.
(*From article by Godfrey Page, October issue, 1921.*)

of which it is built, it may perhaps be said that the reinforced concrete building which Mr. E. Godfrey Page presents as the engineer's design (*Fig.* 1) in his most interesting and instructive article on "The Decorative Treatment of Concrete" in the October number of this paper, is to be preferred to the architect's variation (*Fig.* 2, also taken from Mr. Page's article) when judging them by the extent to which the designer has succeeded in giving expression to the properties of the material employed. The building in *Fig.* 2 of that article would hardly convey the impression to the ordinary man in the street that he was facing a structure built of a new material: a material to that degree different from the old ones that in many ways it has revolutionised building technique and produced new means of solving innumerable constructional problems which in former days were beyond reach for theoretical, practical and economical reasons. The casual observer would possibly rather come to the conclusion that the building was of the same construction, structural steel frame with cut stone facing, as the several large department stores which at the present time are under construction in London.

It can also be surmised that no architect would design a mill building to be situated somewhere in the open country, or a warehouse to be erected in the industrial outskirts of a city, as the one shown in *Fig.* 2, nor would any engineer erect a department store on the corner of Bond Street and Oxford Street, for instance, and give it a façade as depicted in *Fig.* 1.

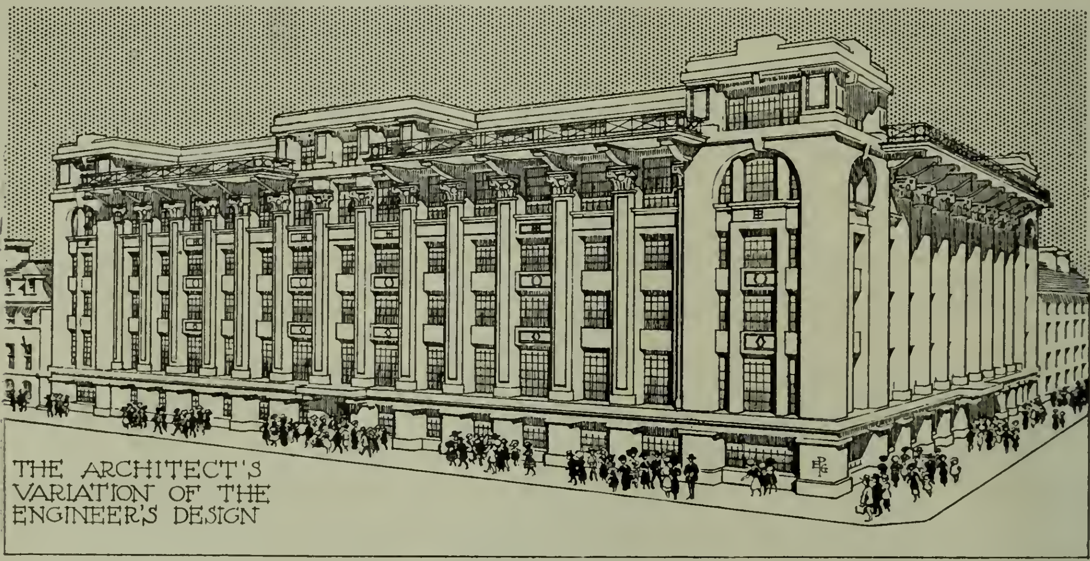


FIG. 2. THE ARCHITECT'S DESIGN.
(*From article by Godfrey Page, October issue,* 1921.)

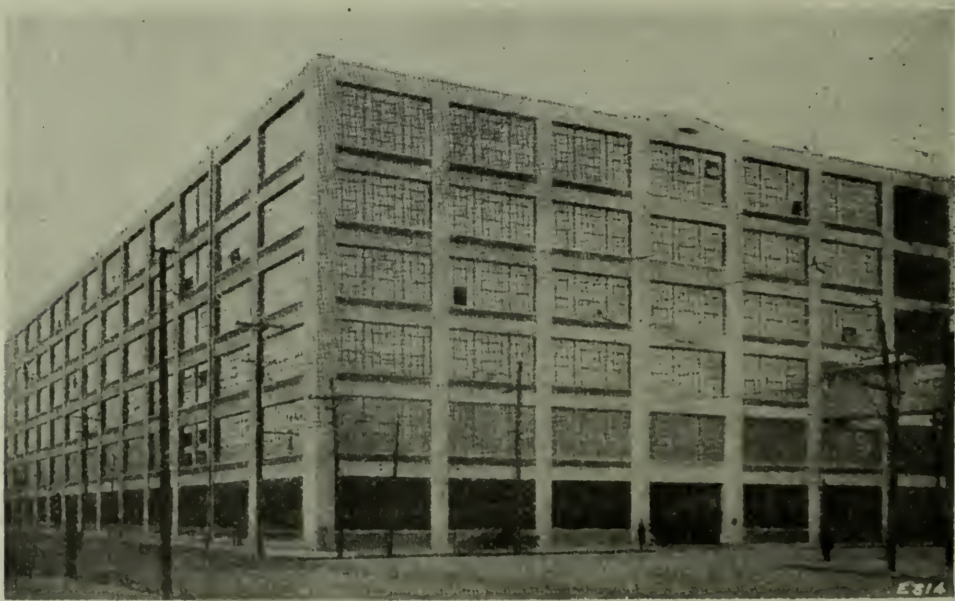


FIG. 3. A FACTORY.

It should in both cases be feasible to state clearly and in an easily comprehensible manner the nature of the material, and yet suitable expressions found in the decorative treatment of the façades for the differences in use and location of the two buildings.

The mill building would merely indicate by means of very simple lines—and derive a certain charm from that simplicity—the general character of reinforced concrete and the constructional problems involved, while the department store, without deviating from the guiding principle of treating structural concrete solely on its own merits, should be the result of the constant close co-operation

FIG. 4. A MILL BUILDING.

FIG. 5. A FACTORY.

between the architect and the reinforced concrete specialist right from the beginning, resulting in an artistic treatment of the material which should perhaps rather err on the side of simplicity than of overloading with decorative details.

FIG. 6. AN HOTEL.

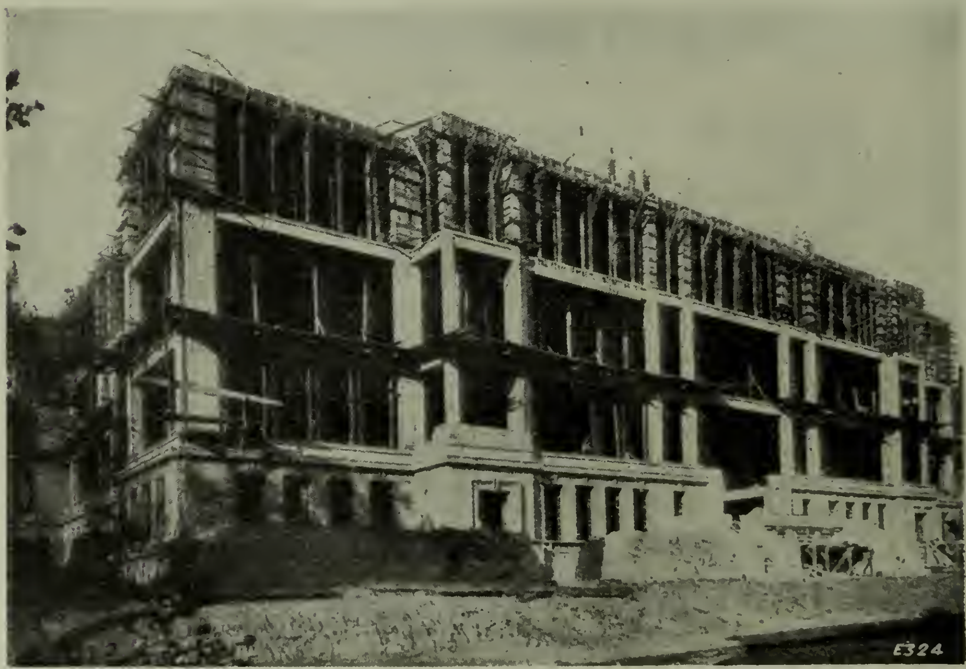


FIG. 7. A SCHOOL BUILDING UNDER CONSTRUCTION.

FIG. 8. A SCHOOL BUILDING.

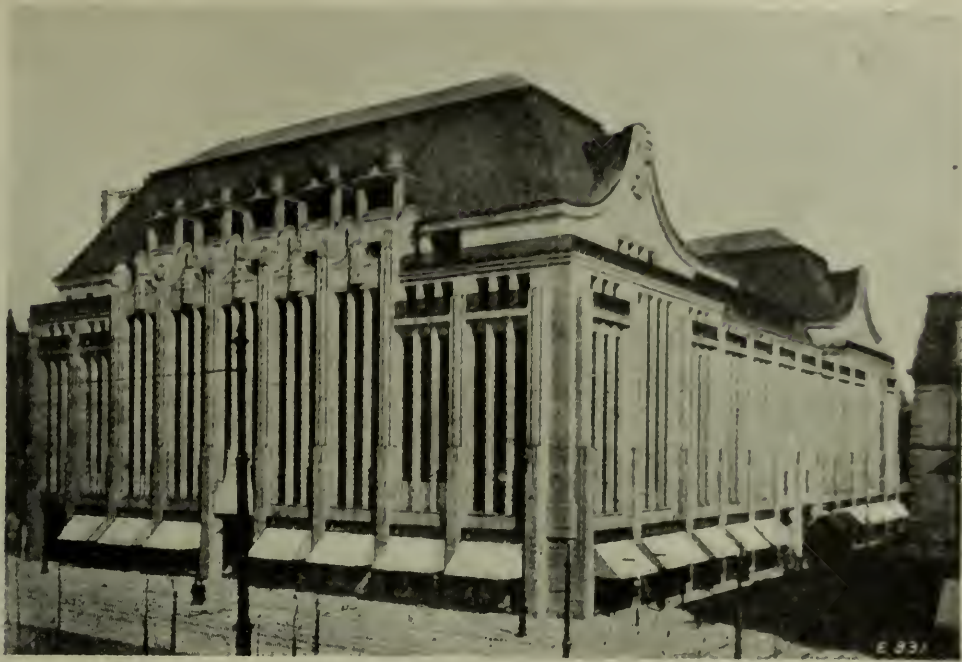


FIG. 9. A DEPARTMENT STORE.

FIG. 10. AN OFFICE BUILDING.

The writer has endeavoured to show by the aid of the accompanying illustrations (for the greater part of which he is indebted to the American Portland Cement Association) that examples can readily be found amongst reinforced concrete structures already erected, which would be suitable for the whole range of buildings lying between the mill building in *Fig.* 1 and the structure in *Fig.* 2.

The factory building shown in *Fig.* 3 and the mill building illustrated in *Fig.* 4 are merely expressions of pure utilitarian and elementary constructional problems without being quite as bare and unattractive as the building in *Fig.* 1. Much more pleasing effects have been attained by the designer of the factory in *Fig.* 5 at a very small additional expense, which presents a very pleasing and suitable reinforced concrete structure for its purpose.

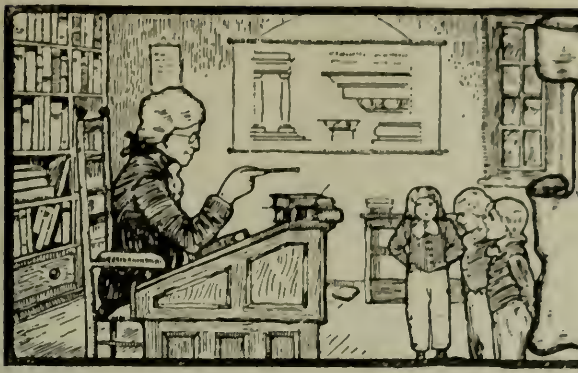
Another building (containing offices for a large industrial concern), also cast entirely *in situ* and showing a similar simplicity of lines, is depicted in *Fig.* 10. It forms, so to say, a transitional link between the factory on the one side and the building in *Fig.* 6, which houses one of the best Chicago hotels outside "the loop district," situated as it is in a high-class residential district on the north side of that city at one of its most important thoroughfares, Sheridan Road, where it is only a few hundred yards from Lake Michigan. It was designed in reinforced concrete by one of the leading firms of architects in Chicago, who have succeeded in fitting this structure of very plain and simple lines most pleasingly into its beautiful surroundings.

Figs. 7 and 8 are illustrations from the class of school buildings, the former showing a building under construction somewhat of the same type and size as the completed structure in *Fig.* 8.

An instance is given (*Fig.* 9) of a reinforced concrete department store erected in one of the main streets of a large city (Düsseldorf).

MEMORANDUM.

Reinforced Concrete Crush Barriers.—An interesting addition to the many structures now being made of concrete, for which, hitherto, wood or iron has been used, is the application of this material to crush barriers, erected at Firhill Park, for the Partick Thistle Football Club Ltd. As in other cases considerable defects have arisen in the use of timber and iron owing to deterioration setting in and causing collapses when heavily stressed ; with concrete, however, a very considerable portion of the cost of the barriers was saved in the first year as repairs, renewals and insurance were almost nil. The standards and rails were pre-cast separately and the reinforcement suitably arranged, so that a rigid structure was given when completed. Special moulds were used, with adjustable plugs. The results have proved highly satisfactory. and we understand that the contractors, Messrs. The Kelvin Construction Co., Ltd. (Glasgow), have other fields under consideration for similar treatment



SIMPLE EXAMPLES OF REINFORCED CONCRETE DESIGN.

(Continued.)

By OSCAR FABER, O.B.E., D.Sc., etc.

Example 3.

Concrete floor slab and beams of single span to cover 100 ft. by 25 ft. (see *Fig.* 6) live load (for offices) 100 lb. a square foot.

The desirability of beams follows from the fact that a slab to span 25 ft. direct would be too heavy and expensive.

This may easily be seen as follows :—Adopting the rule for slab thicknesses given in *R. C. Simply Explained*,*

thickness equal to $\frac{1}{24}$ span,

this would clearly give a slab just over a foot thick, weighing 150 lb. a foot, or 250 lb. a foot with the live load.

Actually this rule only applies to continuous slabs, with a total load of about 175 lb. per foot, so that in the present case a 15 in. slab would be needed.

This would be a very heavy and expensive floor. In general, the arrangement of beams should be so chosen as to give slab thicknesses not exceeding 6 in.

Slab.—We will therefore adopt the arrangement of *Fig.* 6, namely span the 25 ft. with beams 10 ft. apart, which will clearly require about a 5 in. slab, working from our rule already referred to.

A 5 in. slab should have $\frac{7}{16}$ in. rods at 6 in. centres (see *R.C.S.E.*, p. 24).*

As a check on this simple design, let us calculate the slab out more fully.

The loads for a 5 in. slab will be

live	load	100	lb.	per	sq. ft.
dead	,,	62½	,,	,,	,,
total	,,	162½	,,	,,	,,

The bending moment may be taken at $\frac{Wl}{12}$ for continuous beams or slabs (see *Fig.* 6 (*e*) of *R.C.S.E.*),†

$$\text{so that } B = \frac{Wl}{12} \text{ on a strip 1 ft. wide and 10 ft. span } (b = 12 \text{ in.})$$

$$= \frac{(162\tfrac{1}{2} \times 10 \text{ ft.}) \times 120 \text{ in.}}{12}$$

$$= 16{,}250 \text{ in. lb.}$$

Now with ·675 per cent. of steel and usual stresses, the resistance moment is

$$R = 95\, bd^2 \text{ in. lb.}$$

so that

$$95\, bd^2 = 16{,}250$$

and

$$d = \sqrt{\frac{16{,}250}{95 \times 12}} \text{ (since } b. = 12 \text{ in.)}$$

$$= 3{\cdot}8 \text{ in.}$$

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* Note.—In these articles, *R.C.S.E.* refers to *Reinforced Concrete Simply Explained*, published by Messrs. Hodder & Stoughton, which appeared in monthly instalments in Concrete.

† The reader is reminded that we are confining ourselves deliberately to simple solutions of sufficient accuracy for work where the utmost economy is not required, this being only securable by an expert designer.

Area of steel $= \cdot 675$ per cent. of effective concrete

$$= \frac{\cdot 675}{100} \times 3\cdot 8 \text{ in.} \times 12 \text{ in.}$$

$= \cdot 31$ sq. in. per ft. width.

Now the area of a $\frac{7}{16}$ in. rod is $\cdot 15$ sq. in., so that $\frac{7}{16}$ in. rods at 6 in. centres gives $\cdot 3$ sq. in. per ft.

To the effective depth of $3\cdot 8$ in. has of course to be added enough concrete to cover it. So that a 5 in. slab with $\frac{7}{16}$ in. rods at 6 in. centres will do well.

As a matter of fact, the slab could be as little as

$$3\cdot 8 + \cdot 7 = 4\cdot 5 \text{ in.}$$

in thickness, $\cdot 7$ being the cover ($\cdot 5$ in.) plus half the diameter of the rod.

Now this calculation applies strictly speaking to the eight interior slab panels only. The two end panels are subject to a greater moment, because these are continuous at one support only.

In general, these should be designed for

$$B = \frac{Wl}{10},$$

an increase of 20 per cent.

If the slab is re-designed for this increased moment an increased thickness and steel area will result.

It is often undesirable to vary the slab thickness in the end panels, and in such cases it is satisfactory to obtain the whole increased strength by increasing the steel by 40 per cent.

In our present case, this would be met by putting the rods $4\frac{1}{3}$ in. centres instead of 6 in. centres, though for practical reasons 4 in. centres would probably be adopted.

The arrangement of slab bars is shown in *Fig.* 7, and it will be seen that the negative moments over the supports $\left(\text{equal to } \frac{Wl}{12}\right)$ are fully provided against.

BEAMS.—Load per beam

		lb.
	25 ft. × 10 ft. × $162\frac{1}{2}$ =	40,625
wt. of beam	say 25 ft. × 300 lb. =	7,500
		48,125

It will be seen that it is necessary to assume a reasonable weight for the beam, though this requires correction after the calculations are further advanced.

Bending moment for simply supported beams uniformly loaded (see *R.C.S.E*, *Fig.* 6 (*d*)),

$$\text{is } B = \frac{Wl}{8}$$

$$= \frac{48{,}125 \times 300 \text{ in.}}{8}$$

$= 1{,}805{,}000$ inch lb.

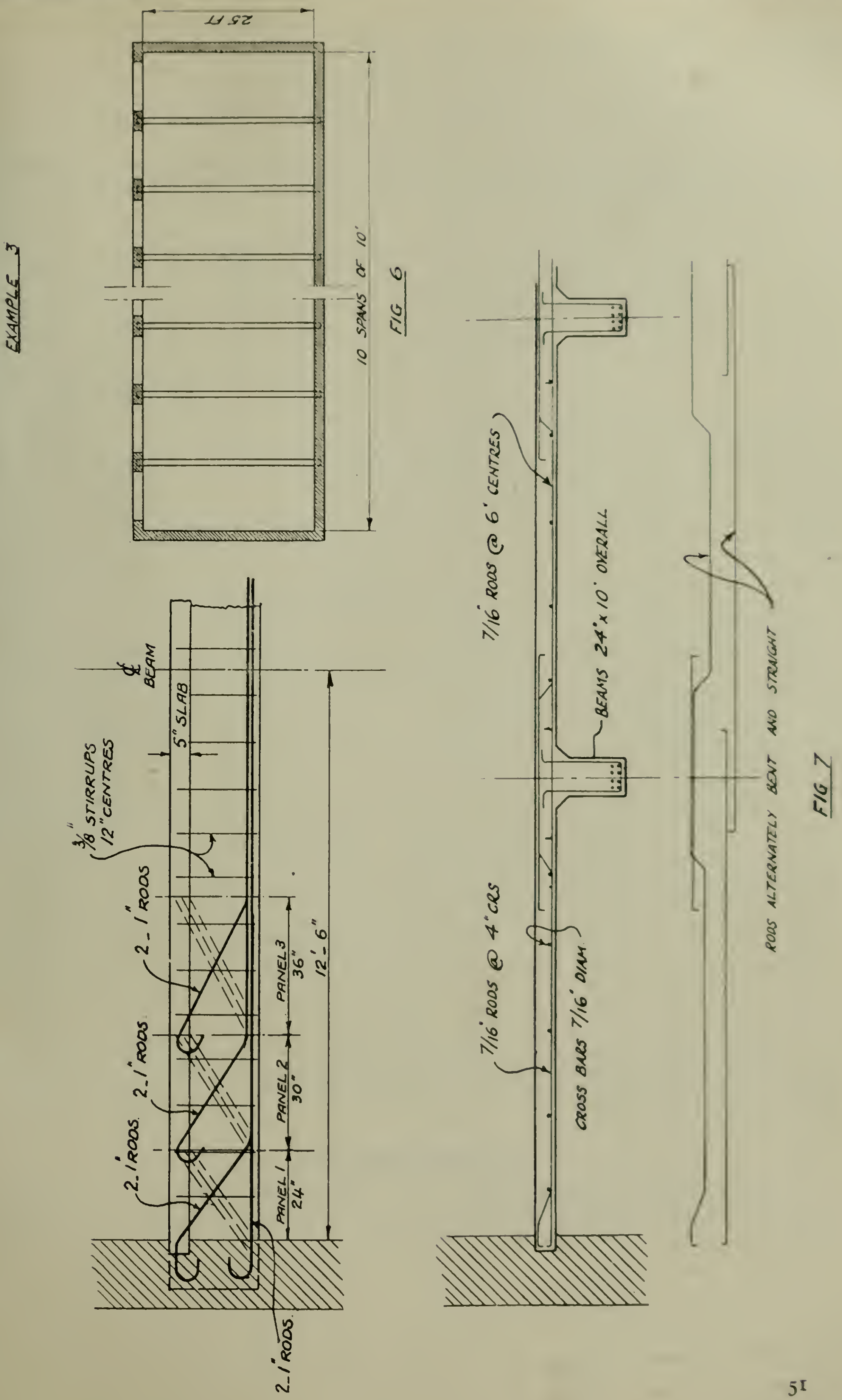
Referring to the author's table of Standard **T** beams (see *R.C.S.E.*, p. 35), it will be seen that beam 24 in. × 10 in. overall with 8 1 in. rods, gives an ample resistance moment.

Now we must see whether our concrete slab is sufficiently strong to act as the compression member to our beam.

Referring back to our table of Standard Beams (*R.C.S.E.*, p. 35) it will be seen that this beam needs a slab 7·9 in. thick and 42·3 in. broad.

Actually our slab is 5 in. thick and, according to the L.C.C. requirements, the safe width may be taken as the least of the following three :

(*a*) distance between beams = 120 in.
(*b*) one third the span = 100 in.
(*c*) twelve times slab thickness = 60 in.


EXAMPLE 3
25 FT
10 SPANS OF 10'
FIG 6
3/8" STIRRUPS 12" CENTRES
℄ BEAM
5" SLAB
2-1" RODS
2-1' RODS
2-1' RODS
2.1' RODS
2-1' RODS.
PANEL 1 24"
PANEL 2 30"
PANEL 3 36"
12'-6"
7/16' RODS @ 6' CENTRES
BEAMS 24' x 10' OVERALL
7/16' RODS @ 4' CRS
CROSS BARS 7/16' DIAM
RODS ALTERNATELY BENT AND STRAIGHT
FIG 7

In our case, therefore, we supply a slab 5 in. × 60 in., which is practically equal to the 7·9 in. × 42·3 in. asked for by the table.

In any case, the reasoning on which requirement (*c*) above is based is very obscure, and the author would not mind taking a greater width of slab as acting.

Coming now to the Shearing Resistance, the shear per beam at the end is

$$S = 24{,}063 \text{ lb.}$$

If we adopt the arrangement of bent-up rods shown in *Fig.* 7, increasing the slope towards the end where the shear is greatest, the shear resistance will be

Shear Resistance in Panel 1 due to

		lb.
Inclined tension	$= 2 \times \cdot 78 \times 10{,}000^* \times \frac{20 \text{ in.}}{30 \text{ in.}}$	= 10,400
Inclined compression	. . . . .	= 10,400
Stirrups	$\cdot 22 \times 10{,}000^* \times \frac{20}{12}$ . . .	= 3,600
		24,400 lb.

Shear Resistance in Panel 2 due to

Inclined tension	$2 \times \cdot 78 \times 10{,}000^* \times \frac{20}{36}$.	= 8,600
Inclined compression	. . . . .	= 8,600
Stirrups	. . . .	= 3,600
		20,800 lb.

$$\text{Actual Shear} = 24{,}063 \times \frac{10\frac{1}{2}}{12\frac{1}{2}} = 20{,}200 \text{ lb.}$$

Shear Resistance in Panel 3 due to

Inclined tension	$2 \times \cdot 78 \times 10{,}000 \times \frac{20}{42}$.	= 7,400
Inclined compression	. . . . .	= 7,400
Stirrups	. . . .	= 3,600
		18,400 lb.

$$\text{Actual Shear } 24{,}063 \times \frac{8}{12\frac{1}{2}} = 15{,}500 \text{ lb.}$$

Shear Resistance in Panel 4.

Inclined tension in concrete 20 in. × 10 in. × 60 in = 12,000 lb.

$$\text{Actual Shear} = 24{,}063 \times \frac{5}{12\frac{1}{2}} = 9{,}700 \text{ lb.}$$

The treatment of Shear follows that fully explained in *R.C.S.E.*, Chap. IV.

* We are adopting a low stress in the shear members, as recommended in *R.C.S.E.* This is because high stresses near bends involve excessive compressive stresses in the concrete.

MEMORANDUM.

Concrete Roads at Middlesbrough.—The scheme for new roads at Middlesbrough that are actually in hand includes eleven roads to be laid in concrete at a total cost of about £45,000. The Walker-Weston reinforcement is to be used for this work.

CEMENT NOTES.

By Our Special Contributor.

Testing Firebricks for Cement Kilns.

The volume of Tentative Standards for 1921 published by the American Society for Testing Materials contains suggested methods of testing refractory materials which are of interest to the cement manufacturer in connection with the firebricks used for lining cement kilns.

The first test is for "slagging action," and consists of cementing a fireclay ring —2½ in. inside diameter, ½ in. deep and with walls ½ in. thick—upon the surface of the brick to be tested. The brick is then put in a furnace and heated to 2462° F., when 35 grammes of powdered slag is emptied into the ring and the heating is continued for two hours at the same temperature. After cooling, the brick is sawn or cut through the centre of the ring and the extent to which the slag has penetrated is seen by the discoloration of the section of the brick. The area of discoloration is measured by a planimeter, and is an indication of the penetrating action of slag upon the brick under test. The composition of the fireclay ring is specified as also that of the slag, of which the melting point is 2318° F.

The second test for firebricks is for resistance to spalling action under rapid temperature changes. The brick under test is heated for five hours at 2552° F. and weighed on cooling. It is then placed in a door of a furnace heated to 2462° F., so that only the 2½ in. by 4½ in. end is subjected to direct heat, and after one hour of this treatment the brick is stood on end in flowing cold water so that the hot end is immersed to a depth of 4 in. After three minutes the brick is withdrawn from the water, allowed to steam five minutes and then returned to the furnace. The alternate heating and cooling is continued in hourly cycles until the end of the brick spalls off. The resistance to spalling is then gauged from the number of dips before spalling commences, the approximate loss in volume after each cooling, the total number of dips and the final percentage loss in weight.

The same volume also describes a standard method for determining the fusibility of coal ash—information which may have some bearing upon the formation of clinker rings in rotary kilns and which is certainly an important factor in connection with the stoking of boilers. The coal ash is moulded into a cone with dextrin solution, and after drying, the cone is mounted in a furnace fitted with a pyrometer and an observation window. The temperature at which the ash begins to soften and is completely fused can then be observed with a considerable degree of accuracy.

Cement Works Chemistry.

The cement works chemist who is a chemist generally feels somewhat ashamed of his position on a cement works on account of the limited scope of chemical supervision, and it is not surprising that the trained man frequently takes the first opportunity of deserting the calcimeter for the Manager's office.

At a cement works that has passed the development stage, the chemist's duties are confined to regulation of the proportion of lime in the cement, with occasional checking to detect any tendency to excess in insoluble matter, sulphuric anhydride and loss on ignition. The percentage of lime is usually fixed on an empirical basis, simply because any excess would lead to unsoundness and any deficiency to reduced strength of the cement, and the chemist is more often than not in the humiliating position of maintaining a mixture that was arrived at by his forefathers by trial and error methods without any acquaintance with chemistry.

Cement chemistry is so much in its infancy that the chemist is still unable to state the reason why a variation of 1 per cent. of lime in a cement may ruin the quality, and while there is good reason to believe that the chief chemical compounds in cement are tricalcium silicate, dicalcium silicate and tricalcium aluminate, the chemist is unable to determine the respective proportions of these in any particular cement or to say in what proportions they should exist to make the best cement. Not until the chemist has solved these problems will his status on a cement works be worthy of his training, nor will the manufacture of cement have left the rule-of-thumb region in which it originated for the basis of a chemical industry, and so enable the clumsy empirical tests which now characterise all cement specifications to be replaced by definite chemical tests for the essential components of cement.

Taking it for granted that the chief components of cement are tricalcium silicate, dicalcium silicate and tricalcium aluminate, each of these compounds at a specified fineness of grinding would develop fixed and invariable strengths at definite periods after mixing with water, and thus if the chemist knew enough to determine the proportions of these components, the strength of the cement could be calculated, and tensile or compressive tests with all their variations due to the personal element would be unnecessary.

An attempt has recently been made by R. J. Colony in America to calculate the proportions of the principal components of cement from an ordinary analysis, but this system of indirect analysis is subject to so many errors that the results are of no value. The subject is, however, worthy of repeated efforts and any discussion is to be encouraged in view of the importance of the possibilities of regularising and improving the quality of cement.

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

In response to a very general request we are re-starting our Questions and Answers page. Readers are cordially invited to send in any questions. These questions will be replied to by an expert, and, as far as possible, they will be answered at once direct and subsequently published in this column for the information of our readers, where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—Ed.

Question.—W. Y. C. writes :—In your November Number there is a very interesting article by Dr. Faber on the design of a circular water tank, 10 *ft. diam.,* 10 *ft. high, which is quite clear and accurate, with the exception of a small arithmetical blunder, which, however, does not vitiate the results, viz. :* $31\frac{1}{4}$ *is the half of* $62\frac{1}{2}$, *not* $32\frac{1}{4}$, *and therefore,* $T = 3{,}050$ *lb., is incorrect.*

In this article Dr. Faber states that with 16,000 *lb. per sq. in. tension in the steel, the concrete will crack, but that "these cracks are so small that in ordinary reinforced concrete structures they do not matter, but in structures depending on the concrete for water-tightness, they are obviously undesirable."*

The author, therefore, recommends a nominal steel stress of 8,000 *lb. per sq. in., and proceeds to show that, owing to the reduction in the stress in the concrete, there is not much likelihood of cracks occurring.*

I should be very glad to know if, in the best practice, this argument holds with reference to structures in salt water, as the corrosion of the steel would probably be more pronounced and more rapid than in fresh water. If not, on what grounds can the steel be stressed higher than 8,000 *lb. per sq. in. ? If above that figure cracks are bound to appear which between high and low water would permit of the access of salt water and air alternately to the steel reinforcement, the worst possible condition for the rapid corrosion of steel. In the article it is definitely stated that the concrete will crack with a stress of* 16,000 *lb. per sq. in. in the steel, and presumably this will apply as much in reinforced concrete wharves and jetties as in water tanks.*

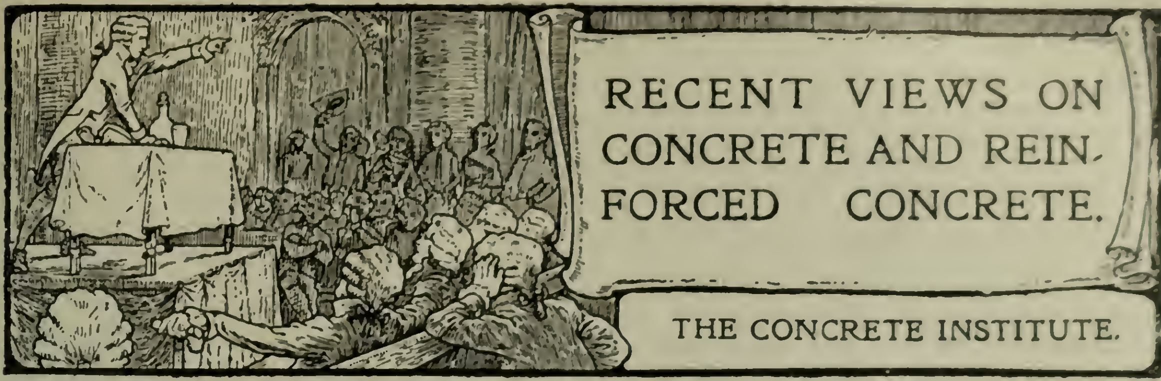
Answer.—It will be noticed from the article referred to that to keep the concrete from cracking, it was desirable not only to restrict the stress, but also the percentage of steel in the concrete ; in other words, not to use too little concrete.

In our opinion the argument, and these conclusions, apply very much to sea-water structures, as your correspondent very properly suggests, and we cannot justify the use of high stresses in such conditions.

It is true that with the present system of design under competitive conditions, many structures are designed in sea-water with high stresses, but many such structures have also shown early signs of serious corrosion (though generally after the period of maintenance had elapsed).

In sea water, the quality of concrete, and the age when first subjected to sea-water, are also important factors in addition to the stresses and design.

O. F.



REINFORCED CONCRETE ROADS:

THEIR RELATION TO THE LAYING AND MAINTAINING OF WATER AND OTHER SERVICE MAINS.

BY CHARLES G. HENZELL, M.Inst.C.E., Waterworks Engineer, Leeds.

Abstract from a Paper presented at a Conference of the British Waterworks Association held in connection with the Public Works, Road and Transport Exhibition.

Owing to the ever-increasing volume of traffic on roads, and also, in a great measure, to the heavier type of transport vehicles now in use, highway authorities are, in busy thoroughfares, having to discard other forms of road construction and put down roads with heavy concrete foundations reinforced with steel or iron.

It is on the main congested arteries of road traffic that this form of road construction is generally adopted, and, as these roads are usually old, it almost always follows that they are comparatively narrow, or, at any rate, they are not wide enough to provide sufficient room for the streams of traffic and at the same time leave suitable margins for the use of departments having underground mains.

Highway engineers are now constructing, or proposing to construct, these monolithic roadways in a very strong mixture of concrete with a thickness of from 5 in. to 9 in., and having a reinforcement of iron or steel in the shape of expanded metal, netting or other fabric.

In almost every thoroughfare in towns the ground directly underneath the road is used by municipal authorities, the Government and companies for the following purposes :—(1) Sewers, (2) water mains, (3) gas mains, (4) electricity mains, (5) telegraph and telephone cables, (6) hydraulic mains.

(1) Sewers.—These sewers are generally constructed at some considerable depth below the surface, and are usually under the centre of the road. They require little attention from the outside of the road, and access is provided for by frequent manholes.

(2) Water Mains.—Ever since the inception of piped water supplies in towns it has been the custom to place water mains under the surface of the roadway, and there is no doubt but that these were the first of the public utility service mains to be laid in that position, and, in spite of the increasing difficulties modern conditions impose upon us, it is still essential that water undertakers should have the full use of the powers contained in sec. 28 of the Waterworks Clauses Act, 1847.

ACCESS TO WATER MAINS.

Water mains are laid at comparatively shallow depths, they require constant attention, are liable to leak or fracture, and access is required to them for the purpose of making connections, cleaning and renewing.

(3) Gas Mains.—These, again, require attention, but not in as great a measure as water mains.

(4) Electricity Mains (Light and Power).—Access is at times required to these for the purpose of new connections and repairs.

(5) Telephones and Telegraph Cables.—These take up a great amount of room. They are generally laid under the causeway.

In addition to these, in the busy parts and the centre of most towns there are the tramways, which take up a large portion of the road, under which it is not advisable to place any service mains.

The main features to be aimed at with regard to water mains are :—(1) Their accessibility for the purpose of making new connections and cleaning out if necessary ; (2) conditions allowing of the rapid location and repair of leakages. The latter is probably the most important point, and in the case of a well-concreted road the leakage does not usually appear on the surface near the point of the leakage. The water often lifts a considerable area of roadway, and finds its way into adjacent cellars. In one case—in Boar Lane, Leeds—the water from a serious leakage appeared over 60 yds. away from the burst, lifted up over 150 sq. yds. of concrete and wood paving, and, by finding its way into the basement of an important shop, caused serious damage, and the repair of the paving alone cost £97. This is only one of many cases with burst mains under concreted roads in Leeds.

Mr. Gray, of the Water Department, Birmingham, in a letter on the subject, says :—

"As regards existing streets in the town, however, this [the laying of service mains under the footpaths on each side of the road] is, in many cases, quite impracticable, as not only are there many mains and sewers, etc., in the roadway, but the pavements also are fully occupied with electric and post-office cables, etc., so that there is absolutely no place to which to move these mains, even if such a plan were thought advisable. If I might make a suggestion, however, there seems to me to be one way out of the difficulty, and that is to lay small land drains—say 3 in.—in rubble all across the road and underneath the concrete at the time the reinforcing of the road surface is being done. These drains would be placed at fixed intervals all along such reinforced roads, and would lead to inspection chambers on the footpaths. In the event of breakage or leakage of water or gas mains, one or other of these drains would then indicate quickly and clearly in which section of the road the defect lay, and this would obviate nearly all unnecessary breaking up of the road surface, as well as saving considerable time in locating the leakage and effecting the repair."

I think it is quite realised that the highway engineer, in constructing the road he deems necessary for modern traffic, will not be inclined to give much consideration to the underground users. The latter have always been accustomed to the use of the road and causeway, and generally they have been able to look after their own interests.

LOCATION OF FAULTS IN UNDERGROUND SERVICES.

The use of heavy reinforced concrete roads, however, sets up new and more difficult conditions for water undertakers and others. So much depends upon the ability to find out the exact point of leakage or burst, and so much depends upon the time it will take to break through and repair the damage, that some scheme must be devised by which this operation can be avoided, or at least shortened and cheapened.

The process of having (in the case of a leaking main) to break through the reinforced concrete road, cut through the ironwork, and after repairing the main, reinstate the roadway, is an exceedingly costly one. In ordinary concrete roads the cost is very great, and a leakage must be found and repaired, or the consequences may be very serious, but with reinforced concrete roads the expenditure will be more serious. Against this I have been informed by a representative of the British Reinforced Concrete Engineering Company that, arising out of a case which came before the London courts in 1915, in which the gas companies were objecting to the use of reinforced concrete work for highways, an actual test was made in order to ascertain the respective times taken to break through plain concrete 12 in. thick and reinforced concrete 6 in. thick, with the result that considerably less time was taken to cut and break through the reinforced concrete.

Take the case of a busy thoroughfare in a large town, where both the road and causeway are almost full of mains belonging to the water, gas and electricity undertakings, and the telephones and telegraphs of the Government, where the traffic on the roadway is both heavy and congested. This is a typical example of the streets that are being "paved" with reinforced concrete. How is it proposed to deal with the mains already laid in such streets? Is the reinforced concrete road to be constructed over the mains without any precautions being taken for their security or their "get-at-ability"? That is a course that can hardly be contemplated, and it will probably be decided that the provision of subways (one on either side of the road) to carry the mains provides the best solution to this problem.

Some of the protective measures to be considered are:—

(1) The laying of stronger mains.

(2) Laying mains at a greater depth to escape the pressure of heavy traffic.

(3) A greater attention to joints and jointing.

(4) The advisability (where the water sets up incrustation) of using self-cleaning ferrules.

(5) The building of manhole chambers where valves and hydrants occur, so as to make them accessible for repairs.

(6) The laying—where possible—of these distribution mains (one on either side of the road) so as to obviate the necessity of crossing the road with the lead service pipes.

(7) The provision of subways.

However one looks at these provisions, the first six of which deal with mains being laid under the roadway as at present, one finds that none of them can be carried out without a good deal of initial expenditure, and it appears to me that if the reinforcement of old and narrow roads is carried out the only permanent solution is the construction of subways, where suitable, for the carrying of the service mains for water, gas and electricity on either side of the road, as it will be almost impossible to lay connections under the reinforced roadway across the streets.

REGULATIONS AS TO SUBWAYS.

The question of subways appears to provide one of the most important solutions of the difficulty.

I do not know whether regulations with regard to the placing of subways under the causeways or roadway are general throughout the country, but in Leeds a clear space of 3 ft. must be left between the outside wall of the building and the road in order that cellars may be ventilated and lighted. There are also important roads where the cellars come right under the causeway up to the kerb, and in one road (The Calls) in Leeds the cellars take up the entire roadway and no pipes may be taken through them except by special permission. All this means that the subways, if they are to be of any useful width, must go a little under the roadway, and in that case would be under the gulley grates, which are at least 2 ft. 6 in. to 3 ft. 6 in. in depth. Subways would have to be at least 5 ft. 6 in. in the clear, and with the thickness of the cover (to stand the heavy traffic) at least 9 in. with reinforcement there may be a difficulty in getting sufficient fall to allow of the water getting away, especially if the sewer is laid at a minimum depth of 10 ft. to the invert. The subways would, therefore, have to encroach upon the ground underlying the roadway, but, owing to the heavy traffic, it is desirable that this should be as little as possible.

The question of the best position for laying trunk mains and the maximum diameter for pipes to be laid in subways arises, and, looking at it from this point of view, I consider that no pipe over 12 in. diameter should be laid therein; all pipes over that diameter would have to be laid in the roadway, and the old questions of leakages, fractures, and the making of new connections would still remain, with all the added disadvantages of a practically watertight reinforced concrete roadway.

Subways having been adopted and completed, arrangements would have to be made for the different mains to be laid therein. Each department will, no doubt, claim a certain position with room for extensions; there will be the cost of laying the new mains, two of which would be required in the case of water, gas and electricity (owing to the difficulty in crossing the road) instead of one as at present, and connections to the buildings and works adjoining would have to be made and the subways broken through for such connections, or else arrangements would have to be made for openings being left in the wall of the subway, in order to provide for them.

Then again—at crossings at the end of reinforced concrete roads—trunk mains may go one way, distribution mains another, and subways would have to be continued at such points so as to provide for these crossings, and altogether, coping with this problem opens up such an additional prospect of expense and worry as might well make the highway engineer hesitate before applying reinforced concrete road surfaces on congested thoroughfares. These subways would have to be of sufficient size and be easily accessible for the making of connections and for repairs. As mains in subways are mostly placed on brackets on either side, lifting apparatus would have to be devised for the larger mains, and proper means provided for cutting out, removing, replacing, and jointing in the case of a burst main and for water easily getting away by means of gulleys connected with the sewers. Arrangements would also have to be made for the staying of bends.

Experience has shown that very serious damage may take place through the bursting of mains in the subways. We have in Leeds several subways, and advantage has been taken of them in laying mains, but the accessibility for repairs and for making large connections is not very favourable at present, although there is nothing insuperable in remedying that. The use of these subways will increase the cost of the service, as both duplicate subways and mains will be necessary ; but the department will benefit when the saving in the cost of the reinstatement of paving is taken into consideration, and also by the facility in locating and repairing leakages in the subways, as against the cost of locating and repairing leakages under a reinforced concrete road.

WATERWORKS LAW AS TO LIABILITY FOR DAMAGE BY BURST MAINS.

In considering the placing of mains in the subways there arises the question of trunk mains. These take up a considerable amount of space, but as it is not often necessary to disturb them except for repairs to leaks or bursts, it might be better to leave them in the roadway even under reinforced concrete, although in the case of a leakage great difficulty will be experienced in finding out its exact position, and in the case of a burst (and we do get bursts)—owing to the hard and impervious nature of reinforced roads—a very great deal of damage will be done to the roadway, large areas of which will be lifted up and broken, and, by reason of the inability of the water to find an outlet to the surface, it will probably find its way into the basement of buildings, and thereby cause considerable damage. As an example of the disastrous effects of a large burst under a concrete roadway, I would refer to the fracture of a 24-in. main in Hunslet Low Road, in June, 1916. The area of concreted roadway broken was 450 sq. yds., and the trams were stopped for over four weeks (June 23rd to July 22nd). The cost of repaving was £172, and the cost of reinstating tramways amounted to £365.

It is not my wish to appear as an alarmist, but simply to put before you some of the difficulties in the way of providing for our mains (and those of other departments), so as to get the best and most economical results with a type of road which has, without doubt, come to stay, and which will greatly increase the cost of our departments. I am not in any way opposed to this method of roadmaking, and personally desire in every way to help our colleagues, the highway engineers. In putting forward these notes, it was hoped that, by a frank discussion on the subject, some method might be evolved by which our mains and works, together with those of other departments, could be efficiently and economically installed, maintained and renewed. If subways are not provided in the construction of the modern roads in new districts where reinforced concrete is used, then wide causeways or green verges must be provided in order to take the whole of the service mains required for the present and future use of the district, and also to allow of trunk mains being laid therein as well. It will still, however, mean that duplicate mains will have to be laid.

DISCUSSION OF MR. HENZELL'S PAPER.

Mr. J. E. Swindlehurst (Coventry), who opened the discussion, said in considering this question he tried to balance it from both sides, and was perhaps better able to do so than some others. Most of the difficulties occurred in narrow and congested thoroughfares, but he failed to see how the water engineer was going to be hurt. Reinforced concrete would not hurt the water engineer, in his opinion, and, in any event, the highway engineer had to look at the matter as an economic question. It applied mostly to congested areas, and if the highway engineer did not put down the best road he would have it in a continual state of disrepair, and then the inhabitants would complain. There were already concreted roads, and the difficulties would not be increased because of the reinforcement. It was all a matter of mechanical operations in cutting through, and not hand cutting. If they could get a subway large enough in a new arterial road all would be well, but the new arterial roads were being so disposed that subways would not be necessary, but even Mr. Henzell's subway would not take the chief trunk mains, so that he did not get over the trouble. In narrow and congested roadways the cost of subways would be prohibitive. He agreed it was not so easy to locate a burst water main under concreted roads, but he relied on the stethoscope for finding such a burst main, and generally there was not much difficulty in location. The solution of this problem was not in the making of subways. In the case of two new 66 ft. arterial roads in Coventry, he had omitted subways because the advantage did not seem to outbalance the disadvantages, which he regarded as very slight.

Mr. C. H. Priestley (waterworks engineer, Cardiff) generally agreed with the author. Mr. Swindlehurst seemed to think that water mains were in the roadway on sufferance, but in his opinion, water supply was as important as the road itself, and the water engineer should be given every facility to lay mains in the best way. He did not think rubble drains, as suggested by Mr. Gray, would be any good at all, because they would not take the water from a large trunk water-main burst. Mains at present were strong enough for the purpose, and if they were to be made stronger it would mean an increase in the cost of water supply.

Mr. J. W. Liversedge (British Reinforced Concrete Engineering Company) said he had been both a water engineer and a highway engineer, and therefore he could appreciate the paper. The whole point was whether reinforced concrete made the reopening of roads more expensive than was the case already with concrete. With the traffic coming on the roads, engineers were compelled to reinforce the concrete, and by so doing were able slightly to reduce the thickness of the concrete. The way steel was distributed in a reinforced concrete road there was no difficulty in cutting through it, and it could be done quite as easily as with the thicker ordinary concrete. As regards the repairing, there were several methods, but the best was to overlap the surrounding thickness and put the reinforcement in the concrete, thus making it stronger than the original. Engineers, however, would find no difficulty in that. Without heavy foundations there would be continual breakages of the ferrules through the heavy traffic. With new roads, the scientific and economical method was to arrange it so that there was a special place for mains, and the road would not be continually broken up. Probably in the long run subways would have to be built.

Mr. H. Gilbert Whyatt (borough engineer, Grimsby) thought the author seemed to think there was no other side to the question than that of the water engineer, and the highway engineer often took the view that his was the only point of view. Experience had shown that a 12-in. ordinary concrete foundation was more difficult to cut through than a 6-in. reinforced concrete foundation. Traffic conditions necessitated stronger roads, but the cost of making good roads, or of the frequent breakings up by the statutory authorities if the road is not a good one, had to be paid for by the ratepayers, either as such or as consumers. Subways were outside the range of practical politics, because they cost £30 to £40 per lineal yard. He believed that duplicate mains under each footpath were the solution of the difficulty.

Mr. A. E. Collins (city engineer, Norwich) referred to the possibility of danger in subways from explosions due to escape of gas ignited by an electric spark where gas and electric mains were together. In any case, one subway in a road should be sufficient.

Mr. Ll. Robinson (borough electrical engineer, Hackney) thought road engineers should not take too selfish a view on this matter. The idea, of course, was to lay a road which would have the least maintenance, but that could not be considered apart from what was underground. He did not think road engineers on the right lines in going in for such heavy foundations. Another point was the way in which road engineers robbed the other authorities. In his case, he found a 1-ft. trench became 2 ft. when the bill for the reinstatement came in, and that was likely to happen if reinforced concrete foundations became general. He urged the use of reasonable foundations with some resilient covering, such as clinker asphalt. Subways would be out of the question on the question of cost, and what about the danger if a high-tension cable was to "short"? Not only would the gas and water mains go up, but the subway also would go with them.

Mr. T. P. Frank (borough engineer, Plymouth) reminded the meeting that water engineers, highway engineers, and the statutory authorities all existed for the benefit of the public, and should work together to attain the object in view. There should be no difficulty in inventing an apparatus which would locate accurately the position of a water leak. A useful thing would be to have a warning pipe coming through the concrete road, and that should help to locate a burst very quickly in the case of small mains. Where there was a multitude of pipes, subways could be afforded, but in less congested districts subways would be too expensive. Moreover, there would always be a danger of flooding subways from the sewers.

MEMORANDUM.

West Bank Dock Electric Generating Station.—A brief description of this work was given in our last number, and our attention is called to the fact that the work was carried out by Messrs. T. Wilson Lovatt, of Wolverhampton.

SOME ABSTRACTS FROM THE FOREIGN PRESS.

CONCRETE FLOORS WITHOUT SHUTTERING.

A SYSTEM of concrete floors which can be made without shuttering has been devised by Théo Raymond. It consists of a series of reinforced slabs supported on T-beams, these slabs being covered in turn with concrete.

This system has been extensively used for the public buildings in Tunis.—*Le Constructeur de Ciment Armé.*

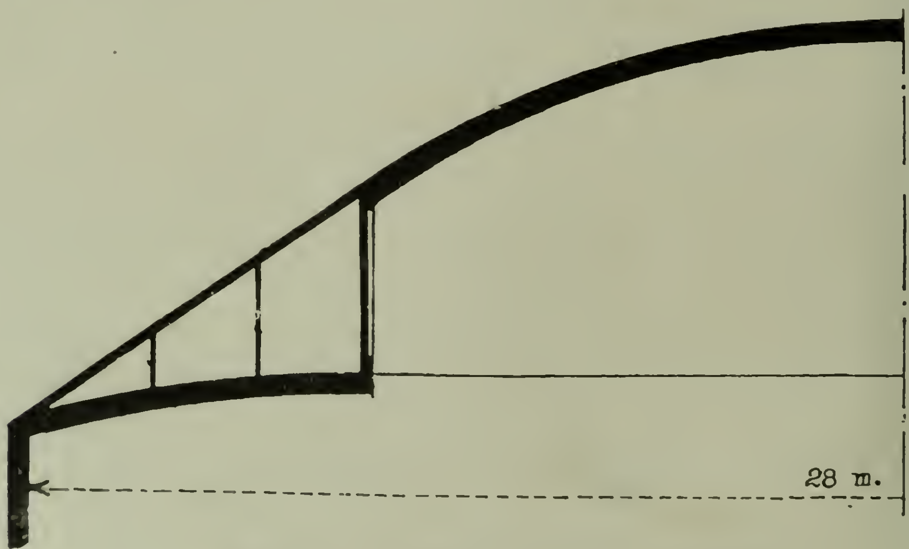
THE USE OF TUBULAR REINFORCEMENT.

A factory recently erected at Lille is interesting on account of the reinforcement being constructed of small pipes or tubes up to 6 in. diameter and $\frac{1}{8}$ in. thickness, strengthened where necessary by spiral wires $\frac{1}{2}$ in. diameter. After the completion of the reinforcement or skeleton, it is completely embedded in concrete mortar so as to preserve it and thus avoid the necessity of frequent painting.

This method of construction also overcomes the chief objection to steel work, inasmuch as the metal being entirely covered by the concrete does not expand readily in case of a conflagration.—*Le Constructeur de Ciment Armé.*

A GARAGE AT GRENOBLE.

The Capuche Garage at Grenoble has an inside width of 93 ft. and two large clerestory lights, 8 ft. high, to ensure ample lighting. These lights raised an interesting constructional problem, which has however been solved quite satisfactorily by the use of reinforced concrete and the use of a series of outer ties, as shown. The secret of success appears to be in the double curvature of the roof, and in the use of truly geometric curves which permit the necessary expansion to take place.—A. Klein in *Le Constructeur de Ciment Armé.*



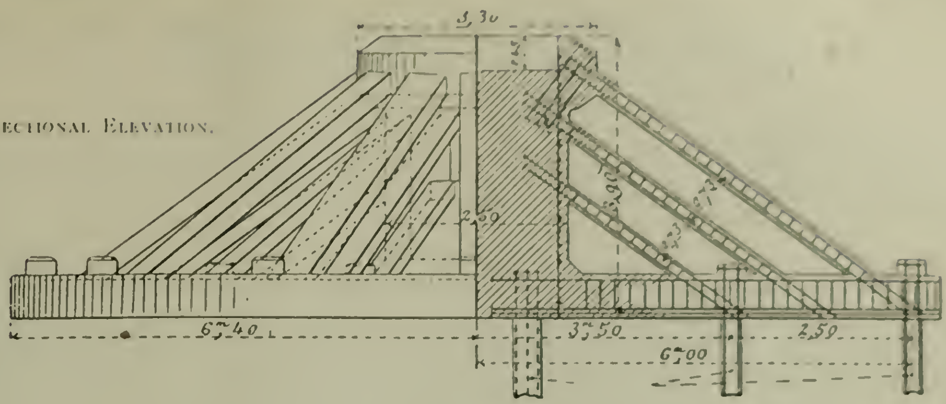
Showing Roof Construction of Garage at Grenoble.

FOUNDATIONS OF THE RADIO-TELEGRAPHIC STATION NEAR BORDEAUX.

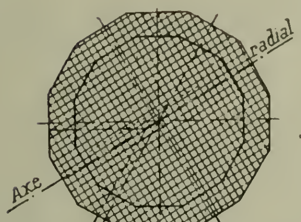
The foundations of the Lafayette radio-telegraph station at Croix d'Hins, near Bordeaux, were designed for a soil whose characteristics were almost unknown, and consisting largely of dune sand, and for resisting wind pressure which had to be assumed rather than determined, so that the engineers were faced with the very awkward problem of providing foundations to support an unknown load on a soil of unknown supporting power.

Tests showed that the ground would carry a load of 2,700–4,000 lb. per sq. ft.

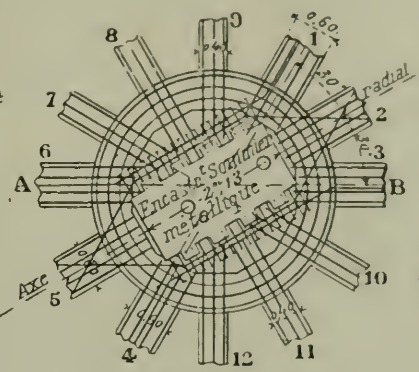
Test piles 13 ft. in length were driven into the ground and showed that the latter had a greater carrying power than might be supposed, though they did not furnish any very precise information. Moreover, the ground was often boggy, so that a light superficial foundation was selected.



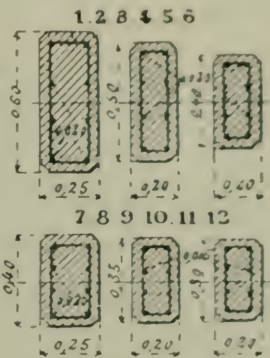
Sectional Elevation.



Plan of Base Grill.



Plan of Upper Part.



Sections of the Angle pieces forming the Concrete Part of the Structure.

Reinforcement of the Base of one of the Pylons.

A consideration of the forces involved showed that the critical position is attained when the neutral axis is tangential to the perimeter of the base; such a condition is comparable to that in a metal prism subjected to a force which limits the attainable elasticity. There is no danger of ruptures, but the greatest care is necessary and the usual rule for such cases limits the forces to half the limit of elasticity.

The details of the concrete raft with overlying base are shown in the accompanying illustrations.—H. de la Noe in *Le Génie Civil.*

CORRESPONDENCE.

Under this heading we invite correspondence.

BUILDING RESEARCH BOARD.

Slag in Concrete.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

DEAR SIR,—With reference to the article on Slag for Concrete in the October number, I would like to invite your readers to give particulars of failures in concrete made with slag aggregate, for the information of this Board. The information is not required for publication and would be treated as confidential.

Yours faithfully,
H. O. WELLER,
Director of Building Research.

The Problem of Collaboration.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

ADVERTING to the Editorial Note in the December issue of your magazine. respecting architects and specialist firms, it might be pointed out that the days when the Vitruvian curriculum (intended to produce the Perfect Architect) was more or less believed in, are now non-existent.

It may be granted that all people could benefit by knowing not alone everything of something, but also something of everything ; but such catholicity of knowledge does not carry in its train the necessary specialistic requirements in relation to building works.

An architect certainly does not need the assistance of a specialist in arranging the ventilating and heating of an ordinary private dwelling ; though I recall that, many years ago, when a client asked my aid in the case of a very badly ventilated room in an old house of his, I called in the assistance of a specialist, not leaving the whole matter in his hands, but obtaining his collaboration, and thus ensuring the completely satisfactory outcome of the work.

But in all works of a public nature, and in large commercial and institutional buildings, good architects make a point of seeking the co-operation of the specialist, whether he be the sculptor, the electrician, the heating and ventilating engineer, the laundry engineer, or what not.

I am not convinced as to the desirability of the structural engineer calling in the services of the architect, but believe fully in the reverse procedure. Only let the structural engineer avoid the abomination of decorated construction, and be satisfied with constructive decoration, and we shall not in future see such abortions as the Tower Bridge, where an architect collaborated, and the Blackfriars Bridge, which is engineering (so-called) architecture.

Writing of bridges, the most recent example certainly shows the successful co-operation of the architect ; I refer to Southwark Bridge, but the success refers to the distinctly architectural portions, for any decent engineer might turn out equally good lamp standards.

But all the same, given a good architect and a good engineer, I see no objection to co-partnership, any more than in the historic instances in other walks, such as Erckmann–Chatrian, Gilbert–Sullivan and Besant–Rice.

Faithfully yours,
PERCY L. MARKS.

SOME OF THE USES OF CONCRETE DURING 1921.

Introduction.

During the past year there has been a considerable increase in the use of concrete both an increase and a development, and perhaps of the two the latter is of the more lasting importance. New uses for this most versatile of materials are constantly being found, so that the phrase "a concrete age" is daily gaining in accuracy whilst losing in picturesqueness.

It will be interesting to note that, with regard to the rapid growth of the concrete industry during recent years, at the present moment there are known to be in the United Kingdom some 270 firms either manufacturing concrete articles or prepared to erect concrete buildings, not including contractors who carry out concrete work on a large scale; and, in addition to these, there are over sixty firms who supply machinery for some form or other of concrete production. This is very significant

Fig. 1. Pier at Shellhaven.

[*Designed by Messrs. Edmond Coignet, Ltd.*]
[*Contractors: Messrs. John Mowlem.*]

when we remember that, only a few years ago, the number of such firms could almost be counted on the fingers of one hand.

The following notes refer to some of the work which has been carried out during the past year by those firms who have responded to our request for information.

It must of course be understood that large and extensive engineering and building works, to the extent of some millions of pounds, have been carried out, but owing to their magnitude it is not possible to include them in these brief notes, and we must rather look to dealing with these from time to time in our pages as occasion arises.

For the purposes of classification we have grouped the following notes under four headings.

Engineering Works, Piling, Etc.

Under this heading we must expect to find a great diversity of work, which, at the outset, indicates the wide and spreading use of concrete. Although this material has for some time been recognised as the most suitable for piers and jetties, this knowledge has not always been acted upon. An interesting example of work of this description is afforded by the new pier at Shellhaven for the Shell-Mex Company, Ltd. (*Fig.* 1), carried out under the supervision and to the designs of *Messrs. Edmond Coignet, Ltd.*, of Gower Street, W.C. The approach to the jetty is 520 ft. long and 18 ft. wide while the pier-head itself is 370 ft. long and 40 ft. wide. The whole structure is carried on reinforced octagonal piles. The contractors are *Messrs. John Mowlem & Co., Ltd.* Amongst much other work which is being carried out from designs by the same firm may be mentioned an important factory at Southall. The contractors here are *Messrs. A. Roberts & Co., Ltd.*, of 74 Earl's Court Road, Kensington.

Another increasing use of concrete is to be found in the construction of bridges, and an interesting example is afforded by a railway bridge recently carried out by *Messrs. F. A. MacDonald & Partners*, of Glasgow, in Almeria in Spain (*Fig. 2*). The bridge spans a public roadway, and is 71 ft. 8 in. long, by

FIG. 2. REINFORCED CONCRETE RAILWAY BRIDGE AT ALMERIA, SPAIN.
[*Designed by Messrs. F. A. Macdonald-Partners, Ltd.*]

FIG. 3. BRIDGE FOR THE MANCHESTER SHIP CANAL CO.

35 ft. 5 in wide. There are four main supporting beams of T section, having a span of 60 ft. 8 in. with bearings, on a masonry wall and on columns; beyond these columns they continue 11 ft. in cantilever. The railway track passes from the bridge on to a viaduct, but there is no structural connection between the cantilevers and the viaduct. The four columns have hinged points at the junction with the base and the beams. The bridge is skewed and the rails have a wide radius curve which does not coincide with the beams. This necessitated designing special floor slabs to meet the load.

Several railway bridges have been carried out by *Messrs. K. Holst & Co.*, of 1 Victoria Street, Westminster, S.W., and the *Reinforced Concrete Construction Co.*, of Elsinore Road, Old Trafford, Manchester, including, by the latter firm, one for the Manchester Ship Canal Co. (*Fig. 3*). This bridge is designed by H. A. Reed, M.Inst.C.E., Chief Engineer to the Manchester Ship Canal Company, to replace an old wooden trestle bridge.

The bridge is in three spans, the length of the main beams of the two end spans being 31½ ft. and of the centre span $37\frac{1}{2}$ ft. To eliminate any possibility of damage through contraction or expansion, the section of beams and decking over each span is a separate unit not being tied in any way to its adjoining section nor to the supporting columns, a space of normally half an inch being left between each section and packed with tow and covered with bitumen to prevent intrusion of grit. The main

FIGS. 4 AND 5. OPEN AIR SWIMMING BATH, LYDNEY.

beams carrying the decking are faced with machined steel bearing plates where they rest upon the column heads and the column heads are also faced with machined steel plates to correspond.

The bridge is supported on twelve octagonal reinforced concrete piles driven to the rock, there being two at each land end, and four, placed in pairs, in the water under each end of the centre section of decking; the heads of the piles forming pairs are connected by a cross brace with heavy gussets at the connections with the piles; from each cross brace springs a column converging to the centre line of the bridge, thus adding to its graceful appearance; each pair of piles is tied to its neighbour and also back to the land piles, which are also tied together, as are also the column heads, the space under the centre span being left entirely clear. All exposed edges of beams, etc., are chamfered and the kerb is surmounted by an iron handrail. The rails are carried over the bridge on longitudinal sleepers laid on specially raised portions of the concrete decking, the spaces between being laid to falls for drainage purposes.

Calculations, drawings and specification were prepared by W. Johnson, M.I.Mech.E., the Manchester Ship Canal Company's Constructional Engineer. Mr. M. B. Lewis, Resident Engineer, Irlam Section of the Ship Canal, was in charge of the work.

Among the most interesting work carried out by *Mr. Peter Fulcher*, of Montpellier Chambers, Cheltenham, may be mentioned an open-air swimming bath at Lydney (*Figs.* 4 *and* 5), built by Lord Bledisloe to commemorate the coming of age of his eldest son. The bath is designed to hold 182,228 gallons, the average thickness of the retaining walls is 8 in. The water is obtained by means of dams from a local stream. Other work carried out by Mr. Fulcher includes various bunkers, bins and a large concrete platform.

The use of the concrete block is rapidly extending to works of first-class magnitude. The *Winget*

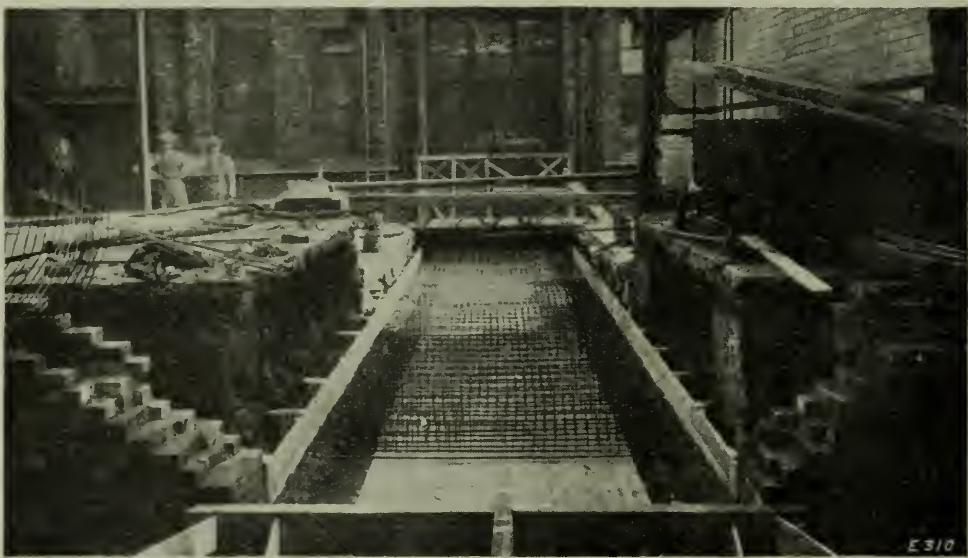


FIG. 6. B.R.C. STIRRUP IN REINFORCEMENT OF ROOF SLAB OVER SUBWAY FOR THE IMPERIAL TOBACCO CO., LTD.

machine has been employed in the erection of buildings in various parts of the world. At Karachi, large revenue offices and an office for the Alliance Branch of Simla, in Mesopotamia railway buildings, at Baghdad a hospital, at Lisbon large hotels; these are some of the larger works in connection with which the Winget block machines have been used. In England perhaps the most striking example of their increased use is afforded by the offices which are being erected by the Office of Works for the Ministry of Pensions at Acton. This vast building, the cost of which is estimated at £500,000, is designed to accommodate some 6,000 clerks.

Many firms who specialize in various forms of reinforcement have extensive lists of works on which they are engaged, or in which their products are used. *The Expanded Metal Co., Ltd.*, of York Mansions, Westminster, S.W., have during the year supplied their expanded steel for almost every class of work in various parts of the country, including rafts, warehouses, foundations, floors, roofs, culverts and reservoirs. The *Indented Bar and Concrete Engineering Co., Ltd.*, of Queen Anne's Chambers, Westminster, have carried out bunkers, factory extensions and water schemes, and two large silos for the Liverpool Grain Storage Co., Ltd., of monumental character, with a capacity of 12,000 quarters. *Messrs. Johnson's Reinforced Concrete Engineering Co., Ltd.*, of Lever Street, Manchester, announce that they have had a busy year and have been engaged on many important works which include factories, warehouses, bunkers and an overhead railway for the Manchester Corporation, retaining wall, wharf and jetty for the British Petroleum Co., and extensive warehouses and jetty on the Thames. *Messrs. McBride & Gray, Ltd.*, of 156 St. Vincent Street, Glasgow, have erected commercial buildings of all descriptions; factories, bakeries, garages, warehouses and offices in Scotland, and in the Midlands. The *British Reinforced Concrete Engineering Co., Ltd.*, of Dickinson Street, Manchester, report an increase in the use of the B.R.C. grouped stirrup; and also an increase in road construction. The grouped stirrup, which is made from a 2 ft. width of B.R.C. fabric, provides in one piece twelve stirrups welded together by cross wires. This forms a unit which is easy to handle and which remains in position. The use of these stirrups is shown in the accompanying illustration (*Fig. 6*) of the roof of a subway at one of the Imperial Tobacco Company's establishments at Liverpool, which is designed to carry heavy road traffic. *Messrs. Brown & Tawse, Ltd.*, of 3 London Wall Buildings, E.C., find that their B. & T. reinforcement is being more extensively used. The wires used for this reinforcement are manufactured from mild steel and are cold twisted.

The use of concrete for piling is rapidly extending, and among the various activities of *Messrs. J. & W. Stewart*, of 12 Berkeley Street, London, during the past year, which includes hoppers, silos, mills and houses, piling figures prominently. This firm has recently acquired the Raymond Concrete Pile, a system which consists of driving a steel spiral reinforced tapered shell into the ground filled temporarily with a collapsible steel core. When this core has reached the desired point of resistance it is collapsed and withdrawn and the shell is then filled with concrete. Grouting is another important branch of concrete work, and *The Side Groove Steel Piling Supply Co., Ltd.*, of 17 Victoria Street, Westminster, have carried out various jobs by means of their Monolith Grouting Pump, which is designed to force liquid grout in a cheap and simple manner into structures that require consolidating after erection.

Fig. 7. A House at Cheam.

Fig. 8. A House at Chaldon.

Fig. 9. A Bungalow at Purley.

Housing,

Each month we have dealt in these columns with a contemporary housing scheme, so that there should be little need to emphasise the development which this side of the industry has undergone in the past few years. Unfortunately the collapse of the Government's housing scheme and the embargo which the Ministry of Health has now placed on housing, has had a very injurious effect, and schemes all over the country, amounting to thousands of houses, have been abandoned. However, houses must be built, and with the advent of more settled conditions we can confidently anticipate a resuscitation of house building. Even despite the adverse conditions many firms have considerably extended their connections.

The Adams Housing Syndicate, of Denham Lodge, Uxbridge, have improved their system of construction, and have also introduced an alternative cavity wall system for which greater flexibility of treatment is claimed, and by means of which many houses and bungalows, including a house at Cobham from the designs of a well-known architect, have been erected.

Many houses have been built by licensees of the P. and P. method of construction, which is the property of *Messrs. Panels, Ltd.*, of 14 Red Lion Square, in the course of the last year. Uni-Constructors, Ltd., of London, have now a scheme on hand for the erection of attendants' houses for the Cheddleton County Mental Hospital for the Staffordshire County Council. This scheme is being carried out under the personal supervision of Mr. Alfred T. B. Kell, M.C.I. We illustrate two houses and a bungalow in Surrey which have been built on the P. and P. system (*Figs.* 7, 8, 9). They indicate that a great variety of treatment is possible by means of the system. The introduction of weather-boarding and tile hanging in gables is particularly effective, while, in the house at Cheam, a legitimate decorative use is made of the structural members, and the pier and panel arrangement is clearly seen.

FIG. 10. A PAIR OF COTTAGES AT CAMBRIDGE.

FIG. 11. TWO VILLAS SHOWING PORCH WITH PILLARS.

The "Doric" system of construction, which has been described in detail in these columns, has made strides in the past year. *The Modern Building Co.*, of Central Chambers, Brighton, which was originally formed as a contracting company for this system, and which carried out various contracts for bungalows, garages and houses, has now been taken over by the *English Asbestos Manufacturing Co.*, of Kingston Wharf, Sussex. A block of buildings is now nearing completion, the contractors for which, under licence, are Messrs. Packham, Sons, & Palmer, of Preston Park, Brighton, and the architect is Mr. Vivian E. Young. The buildings, which comprise a hall, gymnasium, canteen, reading and writing and lecture and billiard rooms, are for Messrs. Thornycroft's Engineering Works at Woolston, near Southampton. The English Asbestos Manufacturing Co. are also supplying their Doric Patent Building Sheets to builders in various parts of the country, who are finding an increasing use for it, quite independently of the Doric system of construction.

During the past year, the *Standard Concrete Construction Co.* of Cambridge have been devoting their attention chiefly to concrete construction as applied to domestic work, having special regard to cost and use of unskilled labour. A pair of test houses has recently been erected at Cambridge from designs by and under the supervision of *Mr. L. Stuart Stanley*, Architect, of which an illustration is given (*Fig.* 10). These cottages were erected for the local authority. It is a cavity wall construction with a T shaped block, brickwork is altogether dispensed with, even for the fireplaces and flues.

Messrs. George Forrester Ltd., of Rutherglen, near Glasgow, have extensively supplied concrete blocks during the past year for domestic and other classes of work, including a large Cinema at Cambuslang. For this some 30,000 hollow rock-faced blocks were used.

Messrs. The Concrete Specialities, of New Queniborough, have been specialising in a 9-in. cavity concrete block, which they manufacture with a rock or panel face. This firm has recently erected some thirty houses with these blocks from the designs of Messrs. Harding & Williams, of Leicester. A pair of these houses is illustrated in *Fig.* 11.

FIG. 12. A SMALL-HOLDER'S BUILDING, COMPRISING CART SHED, STABLE, COW SHED, CALVES' COT, PIGSTYE, MIXING ROOM AND LOFT.

FARM, ESTATE, AND BUILDING ACCESSORIES.

The advantages of concrete for farm and estate building are becoming daily better appreciated, for there is no material that can compete with concrete in these essential qualities: durability, cheapness, cleanliness, ease and speed of erection. The tendency is to deal with agriculture more and more scientifically, and it now demands buildings constructed on hygienic and practical lines, and on all sides is evidence that concrete is gaining favour for this purpose, not only for the buildings themselves, but also for various accessories, such as drinking troughs, paving-blocks, fencing and the like.

The Abdon Clee Stone Quarry Co., Ltd., of Bridgnorth, Salop, have, in the course of the last year, been devoting especial attention to this branch of work, in addition to domestic work. The method of building is by means of a series of standardised reinforced units, by means of which it is claimed almost any design can be successfully undertaken. A small-holder's building which comprises accommodation of a various kind is shown in *Fig.* 12. It will be noticed that the grouping of the building has all that pleasant irregularity which is usually associated with farm buildings and which is termed picturesqueness. A smaller compact and serviceable building is also shown. The walls, as can be seen, are built up on a system of pre-cast posts and panels.

Among the concrete work which *Mr. A. J. King*, of 2 Rutland Road, Harrow, has completed during the year is a large silo, one of two which it is proposed to erect at Loxwood, Sussex (*see Fig.* 13). This silo has a capacity of 350 tons, sufficient for 95 head of cattle at 40 lb. per day for 180 days, and tank for 7,856 gallons. It is 21 ft. in diameter and 60 ft. in height. It is built of concrete blocks made in iron moulds. The walls are 6 in. thick, it has twenty-nine emptying and feeding doors fastened from the outside, which are enclosed in a well lighted reinforced concrete chute. Access to the filling door is obtained from a step-ladder embedded into the wall leading to a projecting platform, which is protected by a guard rail. From this platform the blow-pipe is raised and put into the filling door. The silo is rendered with waterproof cement on the inside.

Concrete threatens to supplant every other material for fencing purposes; its durability, ease of maintenance, and low original cost, are sufficient reasons to account for this. *Messrs. Tidnams, Ltd.*, of Wisbech, have during the past year carried out large fencing contracts, in addition to their general work, for the Air Ministry, Manchester Ship Canal, Bristol Water Works, and many railway companies, county councils, and other public bodies. Many firms have experienced an increased demand for concrete products of a general nature. *Mr. Thos. P. Hall*, of Copmor, Portsmouth, for example, has been supplying reinforced concrete door and window heads, window sills, gate and fence posts, paving and roofing tiles for housing schemes at Portsmouth, Gosport, Havant, etc. Work of a similar nature has been carried out by *The Concrete Brick and Tile Co.*, of Abingdon, and the *Gloucester Concrete Construction Co., Ltd.*, of Hempstead. The manufacture of concrete roofing tiles has received a big impetus in the past year. *Messrs. Henry Wilde, Ltd.*, of 66 Victoria Street, Westminster, particularly report progress in this direction. Mr. William Withers, of Bilston, installed one of Messrs. Wilde's hand machines in connection with his housing contract for the local authority. These tiles proved so successful that it was decided to roof the whole 300 houses with them, and, to expedite the work, an "Ideal" power roofing tile machine and a "Best" mixer were installed. These produce interlocking tiles at the rate of eight per minute. A machine of the same type was supplied to the Redhill Tile Co., Ltd.

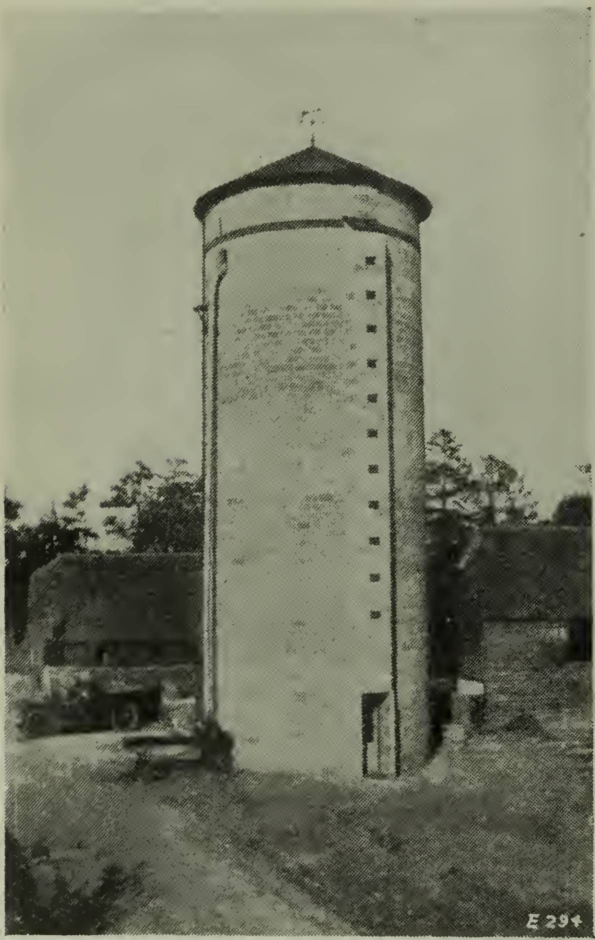


FIG. 13. A SILO AT LOXWOOD, SUSSEX

ROADS.

The period of unemployment towards the close of 1920 caused the Government to put in hand various improvement schemes that had long been overdue, with a view of providing relief. Thus it came about that many arterial and other roads were constructed by municipalities. The fame which concrete roads had been rapidly acquiring throughout the world, decided many of the authorities to make use of this material. They were also guided in their choice by considerations of cost, maintenance, and facilities for the employment of unskilled labour.

An illustration is given (*Fig.* 14) of Southfield Road, Middlesbrough, which was constructed with the Walker-Weston system of reinforcement. This reinforcement consists of a framework composed of $\frac{3}{16}$ or $\frac{1}{4}$ in. diameter bars, varying according to the class of road in top and bottom layers of the framework, the bars in bottom layer are spaced at 6 in. by 6 in. centres, and on top layer 12 in. by 12 in. centres, with No. 6 S.W.G. wire connecting the two layers. The depth is made to suit any thickness of concrete up to 8 in. The weight varies from 10 to 17 lb. per square yard. The specification for this road—one of many carried out for the Corporation of Middlesbrough—specifies concrete gauged $4\frac{1}{2}$ to 1, composed of 3 parts of whinstone $1\frac{1}{2}$ to $1\frac{1}{4}$ in. gauge, $1\frac{1}{2}$ parts coarse pit sand, 1 part of Portland cement, all measured by volume. The total estimated cost was 25*s.* per square yard. This figure, however, is proving to be in excess of actual figures, and it is now hoped that the cost will not exceed 21*s.* to 22*s.* per square yard. This is more than the work would ordinarily have cost but for the extensive employment of unskilled labour. *The Walker-Weston* Patent Pyramidal Interlocking Framework is being employed by many other authorities, including the Middlesex County Council for their North Circular Road, the Norwich Corporation, Belfast, Manchester, Port of London, Somerset County Council, East Ham Corporation, etc.

The British Reinforced Concrete Engineering Co., Ltd., are of the opinion that many more engineers have during the past year arrived at the conclusion that the solution to the road problem lies in the use of reinforced concrete, either as a foundation or as a complete road, and they state that B.R.C. roads are now being constructed as arterial roads for the Middlesex County Council, and that in several provincial towns their system is being employed. The Indented Bar and Concrete Engineering Co., Ltd., have enlarged their roads section during 1921, and have supplied material for roads in various parts of the country. They, moreover, anticipate a further considerable activity as soon as Government grants for road work have been apportioned.

FIG. 14. SOUTHFIELD ROAD, MIDDLESBROUGH.

MEMORANDUM.

A Concrete Railway Bridge over the Rhône for Geneva.—One of the largest and most important bridges built of concrete, and indeed, one of the largest combined railway and vehicular bridges in Europe, to be called the Butin Bridge, is now rapidly nearing completion near Geneva. It crosses the Rhône, near that city, and is intended to carry both a main line railway, a tramway, and a roadway for vehicles and pedestrians. The Butin Bridge extends some 820 feet in length, and stands 164 feet above the (normal) river level. The lower portion will carry a double railroad, and on a higher level will be a roadway, carrying a double set of tram lines, besides the usual pavements for foot passengers. The whole enormous structure is carried out in reinforced concrete by the Swiss engineers and constructors, whose belief in this material, justified by previous experience in building a concrete railway bridge over the River Aar in 1916, is so strong that they have not hesitated to adopt it for this new double bridge, constructed in two levels, and intended to carry an enormous traffic on both of them. Although building stone is, naturally, found in plenty among the many mountains of Switzerland, this more economical, durable, plastic and easily worked material is fast coming into favour among Swiss engineers, architects and builders.

PUBLISHER'S NOTICES.

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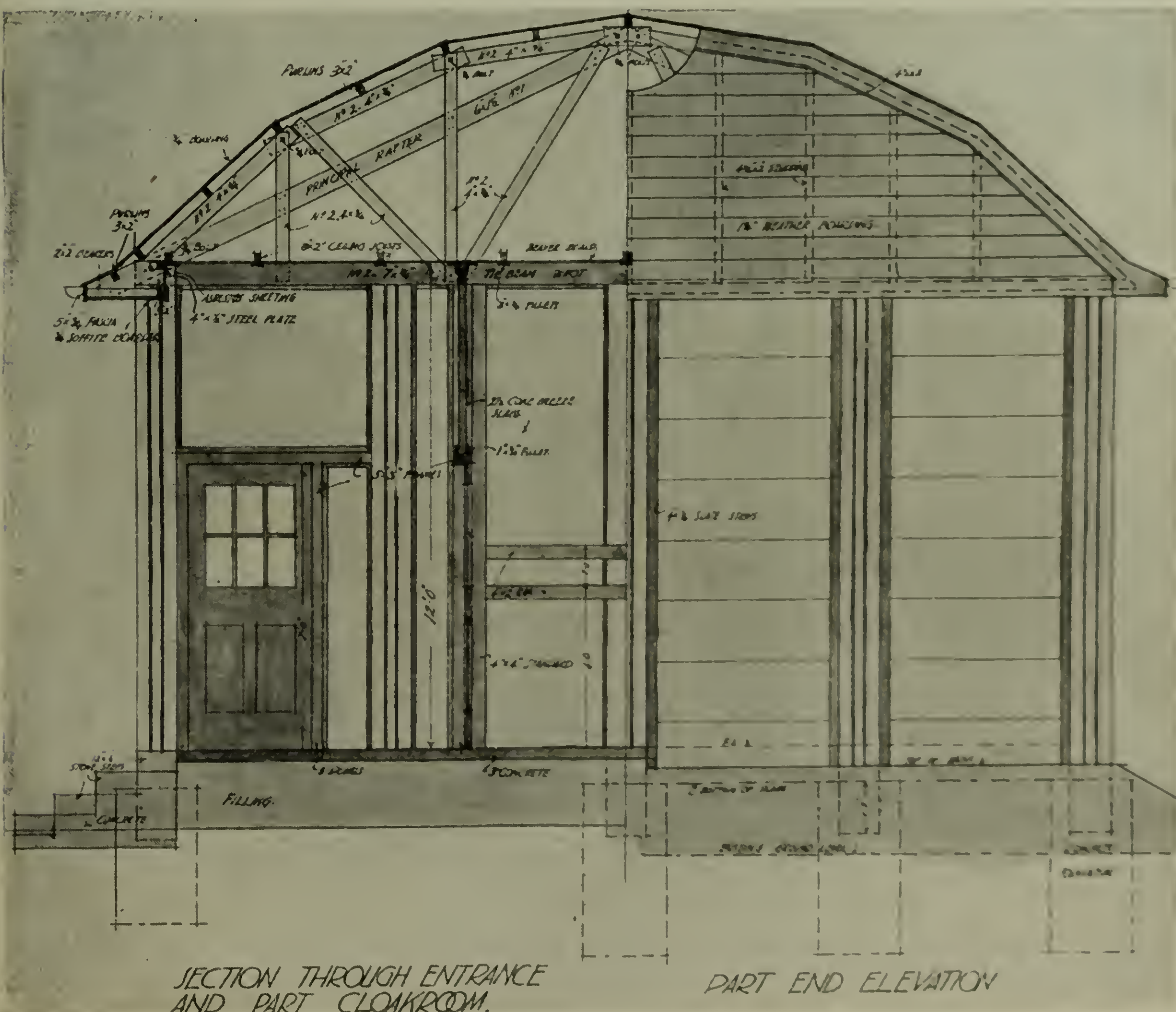
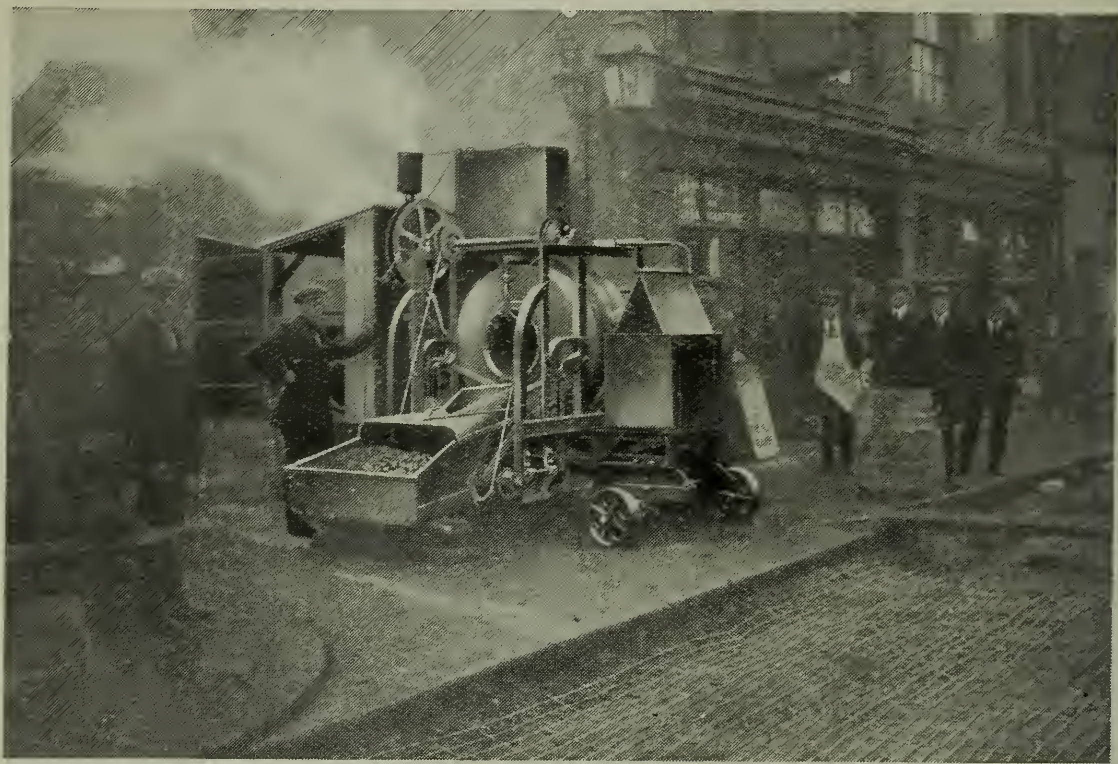
MEMORANDA.

Memoranda and News Items are presented under this heading with occasional editorial comment. Authentic news will be welcome.—ED.

Concrete for School Buildings.—The illustrations on this page and page 75 were shown by Mr. Widdows in the course of a paper on "School Design" at the Royal Institute of British Architects, in November. The building is of a post-and-panel type of concrete construction devised by the architect, and was, he stated, working out at from 11*d.* to 1*s.* per cubic foot, or about the same price as a building of similar size in timber.



SOMERCOTES BOYS' SCHOOL: EXTENSION.
Mr. G. H. WIDDOWS, F.R.I.B.A., School Architect to the Derbyshire County Council.



Concrete Roads.—In our next issue we propose publishing an article on reinforced concrete road work in Leeds, by Mr. L. R. Moir.

SOMERCOTES BOYS' SCHOOL : EXTENSION.
Mr. G. H. WIDDOWS, F.R.I.B.A., School Architect to the Derbyshire County Council.

TENDERS INVITED.

SUNDERLAND.—The Sunderland Gas Company invite tenders (to be submitted by January 3rd) for the construction of a mass concrete gasholder tank, 127 ft. 6 ins. diameter, by 25 ft 8 ins. deep. Further particulars may be obtained from Mr. C. D. Drury, Engineer to the Company, Sunderland. Deposit, £2 2s.

LILLE.—The Municipality of Lille (France) is inviting tenders (to be submitted by February 13), for drainage and sewage works in the Basse-Deule area. United Kingdom firms are invited to tender, and particulars, specifications, and plans may be inspected at the Department of Overseas Trade, 35 Old Queen Street, Westminster, S.W.

BELGIUM.—The sending-in date of tenders for the construction of a dry dock at Lagerbrugge has been extended until February 26, and for the enlargement of the Brussels-Charleroi Canal and the construction of a maritime dock at Kriusschaus and a quay wall at Austruwell until January 16 (See our last issue, p. 835).

WHARF FOR COSTA RICA.—With reference to the proposed wharf in reinforced concrete to be erected at Costa Rica and for which tenders were invited, an extension of time has been granted for the sending in of tenders, which should now reach the Public Works Department of Costa Rica by March 1.

TENDERS ACCEPTED.

CAMBRIDGE.—The Cambridge Town Council has received the following tenders for the erection of twenty houses in Union Lane (the prices are the average price per house) : L. Hale, £975 ; A. Negus & Sons, £873 ; Coulson & Sons, £833 ; Kidman & Sons, £831 ; W. Saint, Ltd., £828 ; J. R. Bennett & Sons, £782 ; Standard Concrete Co., £781 ; G. B. Mortlock, £770 ; Hipperson, £753 ; Brignell, £700 ; Building Guild, £637. It is recommended that the work be apportioned between Messrs. G. B. Mortlock and the Building Guild.

DUDLEY.—The South Staffordshire Waterworks Co. has accepted the tender of Messrs. Davey & Co., Ltd., of Bank Chambers, High Street, Runcorn, for the construction of a reinforced concrete reservoir at Dudley.

LONDON.—The Metropolitan Asylums Board has accepted the tender of Messrs. A. Marton, at £460, for cement backing to walls at the Tooting Bec Hospital Extension.

LONDON.—The Battersea Borough Council has accepted the following tenders : One concrete mixer, Ransome Machinery Co., £275 ; two concrete mixers, C. H. McGuinness & Co., £216.

MARKET DRAYTON.—The Market Drayton Urban District Council has accepted the tender of Messrs. Roberts, Ltd., of Birmingham, at £14,258, for the erection of twenty-four houses. Other tenders received were : Woodhouse (Shrewsbury), £14,580 ; Jackson (Tipton), £15,138 ; France (Oakengates), £15,440 ; Felton (Stafford), £15,491 ; Building Guild, £15,618 ; Deakin (Shrewsbury), £15,812 ; Ball & Sons (Stoke), £15,994 ; Wilkinson (Birmingham), £16,020 ; Millington (Crewe), £16,455 ; Nicholas (Shrewsbury), £16,681 ; Unit Construction Co. (Birmingham), £16,967 ; Treasure (Shrewsbury), £17,000 ; Hayes (Shrewsbury), £19,457 ; Moore (Codsall), £20,755.

MARSDEN.—The Marsden (Yorks) District Council has accepted the tender of Messrs. Holroyd & Brooke, of Marsden, for the construction of a concrete and iron bridge over the river Colne, for £245. Other tenders received were : A. Graham (Huddersfield), £360 ; A. Graham & Sons (Huddersfield), £358 11s. 4*d*. ; J. E. Dyson (Huddersfield), £322 14s. ; J. & G. Bottomley (Marsden), £300 ; J. Wimpenny & Co. (Huddersfield), £288 ; Astley, Brooke & Co., £287 ; J. Cooke (Huddersfield), £279 10s. ; White & Co. (Huddersfield), £250 8*s*. 2*d*.

Sheerness.—The Sheerness Urban District Council has received the following tenders for the construction of 190 yards of 1 ft. 9 in. by 1 ft. 2 in. egg-shape concrete tube sewers and about 1,884 yards of stoneware pipe sewers : T. W. Pedrette, Enfield, £17,717 (accepted) ; Hardy & Co., Woking, £18,170.

Tunbridge Wells.—The Tunbridge Wells Town Council has awarded a contract to Messrs. Strange & Sons, Ltd., at £1,146, for the construction of a concrete tank and foundations for a new cooling tower.

York.—The York Town Council has accepted the tender of Messrs. Ellis & Sons, of Leicester, for the supply of concrete tubes for a new sewer in Huntingdon Road, at 57*s*. 6*d*. per yard.

PROSPECTIVE NEW CONCRETE WORK.

Aberdeen.—*Quay.*—Provost Mearn's Quay, Aberdeen, is to be extended by the Harbour Board, at an estimated cost of £24,000.

Abingdon.—*Sewage Works.*—An inquiry has been held by the Ministry of Health into an application of the Abingdon Town Council for sanction to borrow £9,000 for sewage works.

Ashburton.—*Reservoir.*—A proposal for the construction of a water storage reservoir is being considered by the Ashburton Urban District Council.

Ashton.—*Reservoir and Concrete Tank.*—Schemes are being prepared for the construction of a reservoir and a concrete tank at Greenfield, by the Ashton Joint Waterworks Committee.

Atherstone.—*Water Supply.*—Application has been made to the Ministry of Health by the Atherstone Urban District Council for sanction to a loan of £59,734 for a water supply scheme.

Birmingham.—*Open Air Baths.*—The Baths Committee of the Birmingham Corporation is considering the question of constructing open-air swimming baths at Harborne and King's Heath.

Blackpool.—*Sewage Works.*—An inquiry has been held by the Ministry of Health into an application by the Blackpool Town Council for sanction to borrow £14,000 for sewage disposal works.

Blandford.—*Baths.*—The Blandford Town Council has under consideration the question of providing a swimming bath in the town.

Boston.—*Water Supply.*—The Boston Town Council has decided to proceed with the carrying out of a water supply scheme at a cost of £70,000. Messrs. W. H. Radford & Son, of Nottingham, are the engineers.

Brighton.—*Road.*—Part of the London to Brighton road is to be widened by the Brighton Corporation, at a cost of £100,000.

Buckhaven (Scotland).—*Sea Defence.*—The Buckhaven Town Council has decided to apply to the Scottish Board of Health for permission to construct a sea wall.

Cambridge.—*Sewage Works.*—A Ministry of Health Inquiry has been held into the application of the Cambridge Town Council for permission to borrow £36,000 for sewage disposal works.

Carlisle.—*Road.*—The construction of a new road between Newtown and Dalston Road is being considered by the Carlisle Corporation.

Chippenham.—*Water Supply.*—The Ministry of Health has sanctioned an application of the Chippenham Rural District Council for permission to borrow £6,250 for water supply works.

Colwyn Bay.—*Water Supply.*—An inquiry has been held by the Ministry of Health into the application of the Colwyn Bay Urban District Council for permission to borrow £10,000 for water supply.

Cork.—*Harbour Works.*—The Cork Harbour Board has called in an American engineer to prepare a scheme for improving the facilities at the harbour, at a cost of about £1,000,000.

Dagenham.—*Sewage Works.*—The Ministry of Health has held an inquiry into the application of the Romford Urban District Council for sanction to raise a loan of £81,400 for sewage disposal works at Dagenham.

Dewsbury.—*Sewage Works.*—Application is to be made to the Ministry of Health by the Dewsbury Town Council for permission to borrow £78,000 for sewage works, including the construction of tanks and sewers.

Durham.—*Water Supply.*—An application of the Durham County Water Board for permission to borrow £547,000 for a water supply scheme in the Weardale district has been the subject of an inquiry of the Ministry of Health.

East Ham.—*Sewage Works.*—The East Ham Town Council has decided to apply for the sanction of the Ministry of Health to a loan of £51,898 for sewage works, including the construction of filters and tanks.

Erith.—*Road.*—The Kent County Council has agreed to contribute £35,000 towards the construction of a new road between Erith and Dartford, which has received the approval of the Ministry of Transport.

Finchley.—*Sewage Works.*—A sewage disposal scheme, estimated to cost £25,000, is to be carried out by the Finchley Urban District Council.

Gravesend.—*Sewage Works.*—An inquiry has been held by the Ministry of Health into an application of the Gravesend Town Council for sanction to a loan for sewage works.

Isle of Man.—*Quay Wall.*—A sum of £32,000 has been voted for the reconstruction of the quay wall at Ramsey.

Isle of Wight.—*Road.*—The Ministry of Health has sanctioned the construction of a road between East Cowes and Newport by the Isle of Wight Urban District Council.

Kirkcaldy.—*Sea Wall.*—The Kirkcaldy Town Council is considering the construction of a sea wall and an esplanade in order to relieve local unemployment.

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THE REINFORCED CONCRETE CULVERT AT CRIMDON DENE ON THE NEW COAST ROAD FROM WEST HARTLEPOOL TO EASINGTON.

(*See page 79.*)


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Vol. XVII. No. 2.
February, 1922.

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 2. LONDON, FEBRUARY, 1922

EDITORIAL NOTES.

SMOKE ABATEMENT.

THE patience which individuals may bring to bear in their acquiescence in unavoidable personal evils may be accounted a virtue, but for a nation placidly to tolerate remediable sufferings, wastage, and illness is indicative of a grave national defect; a defect rendered all the more glaring when we observe how other countries, with similar customs, industries, and pursuits have succeeded, if not in entirely ridding themselves, at least of effecting great amelioration from the same evils.

An annual waste of 3,000,000 tons of fuel; an increased cost of household washing, in one town alone, in the course of a year of £290,000; a continual destruction and disintegration of ancient historical buildings, necessitating a never ceasing expenditure for repairs; a lavish annual outlay in house painting; the building, equipment, and maintenance of tubercular sanatoria; the continual damage to agriculture and vegetation; misery, sickness, and dirt in the households of three-fourths of the population; pollution of the atmosphere; a destruction of the beauty of the countryside; these are some of the ills which we suffer through a wasteful and improper consumption of coal. What plea could an individual make against such an indictment? What plea can we as a nation make against such an indictment? None but the frail excuse of apathy, selfishness, and inertia.

One of the prime functions of an elected Government is co-ordination. The various consumers of coal, according to their varied circumstances, as manufacturers, large and small household consumers, town or country dwellers, are differently affected by and interested in the question of coal abatement which must, therefore, be handled nationally and impartially, so that the hardships of the influential few—which can be only financial and temporary—may not outweigh the inestimable benefit to the many. That this much has been realised is obvious from the appointment of a strong committee by the Minister of Health in January, 1920, "to consider the present state of the law with regard to the pollution of the air by smoke and other noxious vapours, and its administration, and to advise what steps are desirable and practicable with a view to diminishing the evils still arising from such pollution." The Committee, which was under the chairmanship of Lord Newton, has now, after two years' hard work, issued its final report.* It is a document of rare moderation and common sense, and perhaps, just on account of these so desirable qualities, will fail to stir the public imagination or to arouse the interest that we fear is necessary to prevent

* Committee on smoke and noxious vapours abatement. Final Report. London. His Majesty's Stationery Office. Price sixpence net.

the Government from thinking that, by the mere appointment of the Committee, it has fulfilled its task and need, for the present at least, take no further action. Indicative of this grave danger is the fact that while the interim report of the Committee, published in June 1920, recommended "that the Central Housing Authority should decline to sanction any housing scheme . . . unless specific provision is made in the plans for the adoption of smokeless methods for supplying the required heat," we know that officials of the very same department that appointed the Committee, viz. the Ministry of Health, were ruthlessly engaged upon the task of scrapping gas installations in housing schemes on account of initial expenditure.

The recommendations of the Committee do not include any drastic alterations to the present laws, but rather a strengthening of those which exist. Local authorities are at present lax in the exercise of their powers and the Committee suggests "that the Minister of Health should be given clearly defined power to compel, or act in place of, any defaulting authority which refuses to perform its duty in administering the law with regard to smoke." Another important suggestion is "that the *duty* of enforcing the law . . . should be transferred from the local sanitary authorities . . . to the county authorities ; minor authorities should still have the *power* to take proceedings if they so desire." This will reduce the number of authorities "having a *duty*" from approximately 1,800 to 140.

Alternatives to the burning of soft coal for domestic purposes are suggested, the most favoured of these being gas and electricity, but the latter is, of course, far too costly for general use, and in many districts the cost of gas makes its general adoption impossible. A recommendation is made with regard to municipal undertakings that the present practice "of overcharging for gas and electricity in order to allocate the profits thus accruing to the relief of the rates should be discontinued." Various methods of central heating combined with domestic hot water supply are discussed, and there is no doubt that manufacturers are giving their serious attention to this aspect of the problem. Here again the Government, in its recent housing programme, wasted invaluable opportunities for installing central heating apparatus.

Observations arising from a visit to Germany undertaken by Lord Newton and Mr. E. D. Simon (Lord Mayor of Manchester ; a good omen for the smoke-laden city) are very instructive. Space will not allow us to make more than a short quotation from this interesting section of the report. "The most superficial investigation . . . discloses an extraordinary contrast between such great industrial towns as Dusseldorf and Cologne, on the one hand, and any comparable British towns on the other. The former are pleasant and agreeable places of residence, and the best proof of their amenity is that even the richest citizens continue to live within the city boundaries, a practice which has long since been abandoned in British manufacturing towns."

Another interesting section of the report is that which deals with the historical aspect of the matter, showing that even in the time of Edward I the evil effects upon the health caused by the imperfect combustion of coal called for proclamations. This, and the illustrated section dealing with historical buildings, show that the report contains matters of interest to every class of citizen : historian, artist, manufacturer, hygienist, statesman, scientist, social-reformer, and above all the man in the street. None can afford to neglect this ever-growing menace to our national health and happiness.

REINFORCED CONCRETE CULVERTS IN DURHAM.

In connection with the new coast road which is being laid from West Hartlepool to Easington, a large culvert as well as a number of smaller ones had to be constructed. The following notes abstracted from a paper by Mr. Wm. J. Mearrett, Deputy County Surveyor, and Mr. C. C. Hancock, Resident Engineer, briefly describe the constructional details of this work ; these notes, together with the illustrations, we are able to reproduce by the courtesy of Mr. Albert E. Brookes, O.B.E., M.Inst.C.E., M.Inst.T., the County Surveyor and Architect of Durham.

A number of natural difficulties had to be overcome in connection with this road scheme, and at one time it was thought impossible of realisation. These difficulties consist of the existence of valleys with precipitous sides, locally known as denes, and extending from the coast line some miles inland.

Transportation of Material to the Site.—In the first place with regard to the question of the transportation of materials to the work at Crimdon Dene, in the first instance considerable difficulties presented themselves, owing to the facts that the nearest railway station (Hart Station) possesses no siding accommodation, and the only route therefrom to the dene was over arable and grass lands. The solution was found by arrangements being made for the use of a small farm siding off the main coast line of the North-Eastern Railway and constructing a 24-in. gauge Decauville track from this siding to the dene, using a light petrol locomotive with a train of wagons.

The use of the 24-in. light rail track has been adopted wherever possible, side-tipping skip wagons of one cube yard capacity being used in connection therewith. Where the tipping distance is short the skip wagons are run and tipped by manual labour, but the longer distances are dealt with by horses and petrol locomotives.

CONSTRUCTIONAL DETAILS.

The difficulties in constructing a passage way across the denes referred to above were considerable and a large amount of thought was needed before any decision could be arrived at as to the best means of carrying the road. The

North-Eastern Railway Coast Line, which runs in close proximity to the new road, is carried over the denes by viaducts of 96 ft., and 139 ft. in height. To follow this practice the cost would have been prohibitive, and in addition skilled labour would have been required, which would have defeated one of the main objects of the scheme at this juncture, viz., the relief of the unfortunate prevalence of unemployment. The County Engineer decided that the most economical method would be to construct embankments. The new road, by its being well graded throughout, results in a number of cuttings, the excavation from which is used to form such embankments. It has been calculated that the quantities of excavation taken from the cuttings will be sufficient to form all embankments.

Taking the road in sections (1) from Hart Station to Crimdon Dene provision had to be made for a water course which runs at the bottom of the dene, and this is made by laying a 48-in. circular tube culvert, the tubes being laid on and surrounded by 9 in. of 7–1 cement concrete.

The Crimdon Dene, which forms the first large natural barrier, is 890 ft. in width and 73 ft. in depth. An embankment formed from the cuttings on either side of the dene crosses nearly at right angles and will contain approximately 180,000 cubic yards of earth. The embankment is 56 ft. in height and is being formed in one tip. The amount of shrinkage of the embankment is an interesting point. Up to the present this has been 7 per cent., but no doubt this will considerably increase as the winter weather affects it.

With regard to the necessary bridging of the stream, Crimdon Beck, this formed rather a difficult proposition owing to the fact that no reliable data could be obtained as to the flow of water which might be expected during flood periods, local reports being greatly at variance. This difficulty was further increased by the following factors, viz. :—

Shortly after the commencement of the work the water in the river entirely disappeared and was discovered to be losing itself through faults in the limestone formation, and the continued drought of the present year did not tend to make the problem any the easier.

It was therefore decided to base the calculations as to the size of the waterway under the embankment by taking the sectional area of the highest flood level which could be found from observation and to allow a sufficient factor of safety of 100 per cent. The decision on this matter has, to a great extent, been justified, as from the result of heavy rains in August last the river rose during one night from entirely dry bed to 4 ft. depth of water. It was fair to assume that if this happened after the long drought of the summer torrential winter rains might suddenly raise the winter flow considerably above its normal level. To cover all eventualities it was decided to construct a reinforced concrete culvert 15 ft. in width and 12 ft. 6 in. in height, the arch and invert being elliptical. The culvert was designed to withstand the weight which will be imposed upon it by 60 ft. of newly tipped earth embankment for the roadway.

The reinforcement consists of a No. 30 section expanded metal with $\frac{5}{8}$-in. supplemental bar reinforcement at the haunches. The invert is now completed. A portion of the side walls and roof is completed and the centres removed.

To economise in timber the supporting framing for the side shuttering and centreing was designed so as to be capable of simple and easy removal from the limited space and to enable the centres to be dropped and the timbering re-used The whole of the supplemental reinforcing bars are made up on the work and the necessary stirrups fixed and are put in position as a braced member complete and the concrete well worked round them.

By good fortune the aggregate for the concrete was found on the site, and after screening and grading required no further handling. The sand, also found on the site, was inclined to be loamy, and was therefore washed prior to use. The water necessary for the concrete work was a serious question owing to the river drying up, and also the drought of the summer affecting all other available supplies. Ultimately the main service pipe from a small reservoir a mile and a quarter away, supplying water to the North-Eastern Railway water tanks, was tapped, and three-quarters of a mile of galvanised iron service pipe was laid.

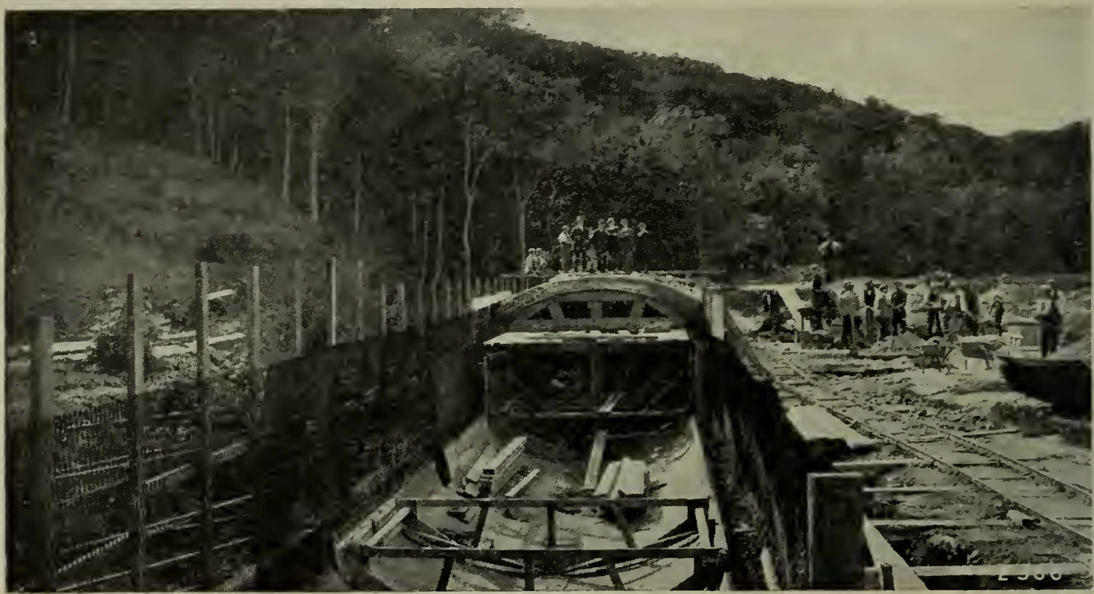
The percentage of voids in the aggregate was 37 per cent. The concrete for the culvert was mixed in the proportions of $3\frac{1}{2} : 1\frac{1}{2} : 1$, which composition was found, after many experiments, to give a resultant with the least amount of voids, and an excellent concrete was made. At either end of the culvert massed concrete wing walls were constructed and parapets formed. The wing wall at the east end of the culvert and on the north side of the stream extends to meet an existing retaining wall belonging to the railway company, and this will form adequate protection for the river bank and one of the piers of the railway viaduct. A relief pipe 36 in. in diameter is being laid in the centre of the embankment at the dene surface level to act as a safety valve should, at any time, the dene itself become flooded. The estimated cost of this culvert is £10,000, the expenditure thereon to date is £6,970, and it is anticipated that the estimated cost will not be exceeded.

Crimdon Dene—Blackhall Village.—From Crimdon Dene to Blackhall Village there are three piped culverts and three smaller embankments.

The Cross Gill section calls for special notice, as it is here the majority of heavy boulders have been encountered, and it would appear that this is due to the fact that this area must have been a "Moraine" resulting from the glacial movement and the large quantity of stone obtained lodgment here. To gain the desired gradients there is a surplus of excavation on this section, but an easy and convenient tip is found in the depressions at Cross Gill. The concrete piped culverts referred to are 3 ft. in diameter and are laid on and jacketed with 6 in of cement concrete.

Blackhall—Horden.—The original proposal in relation to this section was to traverse a route from the termination of the Blackhall Village main street, and to cross the Castle Eden Dene in close proximity to the railway viaduct. It was, however, deemed advisable to abandon this route owing to the possibility of the weight of the necessary high embankment affecting the stability of the piers of the viaduct. The seriousness of this question is exemplified by the fact that the railway company have made special arrangements with the colliery company as regards the working of the coal immediately under and adjoining the viaduct. The present line has now been decided upon and the route crosses three very deep denes—the first, Hardwick Dene, is crossed diagonally, the crossing of Ash Gill and Castle Eden Denes being more or less at right angles.

The cutting to be formed will produce sufficient material for the embankments necessary, and very good gradients are obtained, especially in view of the type of country which is traversed, the maximum gradient being 1 in 18. On this section, in addition to manual labour, the No. 5 Ruston steam navvy is



View of Culvert—Looking West.

Reinforced Concrete Culvert in Course of Construction at Crimdon Dene.

employed, and in conjunction with same 2-ft. gauge Decauville track and skip wagons of 1 cubic yard capacity are used to run the excavated material to the embankment tip.

The general line as followed on the Crimdon Dene section as regards the felling of timber, benching, etc., has been carried out. The stream in the bottom of Hardwick Dene is provided for by the laying down of a 4-ft. concrete tube encased in concrete with a 24-in. stoneware pipe in concrete as above to act as a relief. The length of this culvert is 204 lineal yards. In the watercourse of Ash Gill Dene is constructed a 24-in. pipe encased in concrete. In the case of the third dene, Castle Eden, or Denholme as it is sometimes locally named, the quantity of water to be calculated for in this stream was considerably more than the Crimdon Beck, therefore a larger culvert is proposed. However, similar constructional details were followed throughout, except that the general construction is heavier to meet the altered circumstances. The size of the culvert is 21 ft. in width, 14 ft. in height, and 110 lineal yards in length. There has also to be provided for in the case of this culvert to comply with conditions laid down by

CRIMDON DENE CULVERT—LOOKING EAST.

the owner of the land benching to form a footway for pedestrians for use during normal weather, and in order to provide a way from one side of the dene to the other so as to avoid using the accommodation roads to the new road level.

With regard to the aggregate for the concrete, the fortunate position prevailing at Crimdon Dene did not prevail in this case ; however it was decided to adopt the most economical method, viz., to erect a small crushing plant and obtain the aggregate from large gravel and stones existent in the river bed.

The height of the embankments crossing these denes is 82 ft. 6 in. The nature of the material to be excavated on this section is rather different to that found on other sections, there being stratas of sand and clay resting upon a soft magnesium limestone.

The estimated cost of the completed scheme from West Hartlepool to Easington, and the secondary road to Easington Colliery, is £271,000, and the whole work is to be financed and carried out in a period of three years.

ADDITIONS TO FACTORY AT BIRMINGHAM.

THE illustrations which we herewith reproduce show important extensions which have been recently completed for Messrs. John and Edwin Wright, Ltd., the well-known hemp and wire rope manufacturers, at their Universe Works, Birmingham.

The additions consist in the construction of two reinforced concrete floors on the Coignet System, having a total length of about 343 ft. by a width of about 33 ft., and a lavatory block.

Heavy brick piers and a longitudinal brick wall were also constructed to carry the ends of the heavy reinforced concrete beams of the two floors at first and second floor level. The building is covered by means of a steel roof.

The whole of the structure, which includes a total area of over 90,000 sq. ft.,

was designed in three bays with two central rows of reinforced concrete pillars and external brick piers and brick walls to support the beams and floors. The two first bays were constructed before the war and described with illustrations in a previous number. The work which has just been carried out is, therefore, a completion of the original scheme, which had been held up in consequence of the war.

The ground floor of the present building has been fully occupied ever since the erection of the original structure, a temporary roof having been placed in position over the unfinished portion for this purpose, and has been used as a machine shop for the manufacture of steel wire rope. A separate extension, however, is in course of erection for the manufacture of medium-sized steel wire ropes for general purposes, such as cranes, lifts, marine purposes, fishing, logging and oilwell boring, whilst the ground floor of the building under review is to be used solely for the very heavy machinery necessary for the manufacture of the largest locked coil and flattened strand steel wire ropes in which this firm specialises for mining, aerial ropeways, suspension bridges and other engineering purposes. The piers on each side of the new bay support a girder runway for 20-ton travelling crane, which runs through the entire length of the buildings.

The two upper floors, which are connected by an electric lift to the ground floor, are constructed for a super load of 3 cwts. per square foot. The principal beams have been calculated to support the weight of pulleys and shafting which may be fixed to them, and the lower row of reinforced concrete pillars and the external brick piers are fitted with heavy gussets supporting a crane track.

All the floors are designed with heavy reinforced concrete beams, 16 in. × 40 in., supporting secondary beams, 6 in. × 10 in., the thickness of the

slab being 3¾ in. The reinforcement of the principal and secondary beams is composed of groups of round bars of mild steel, having their ends bent at an angle of 45 degrees and hooked to top longitudinal bars in order to form complete units.

The reinforcement of the pillars is composed of a certain number of vertical bars, tied by means of ties or stirrups of small diameter.

The floor slabs contain a meshwork of principal and secondary bars. The surface of each floor has been covered to a thickness of 1¼ in. with granolithic paving.

The entire construction has been carried out by Messrs. Richard Fenwick, Ltd., Contractors, Birmingham.

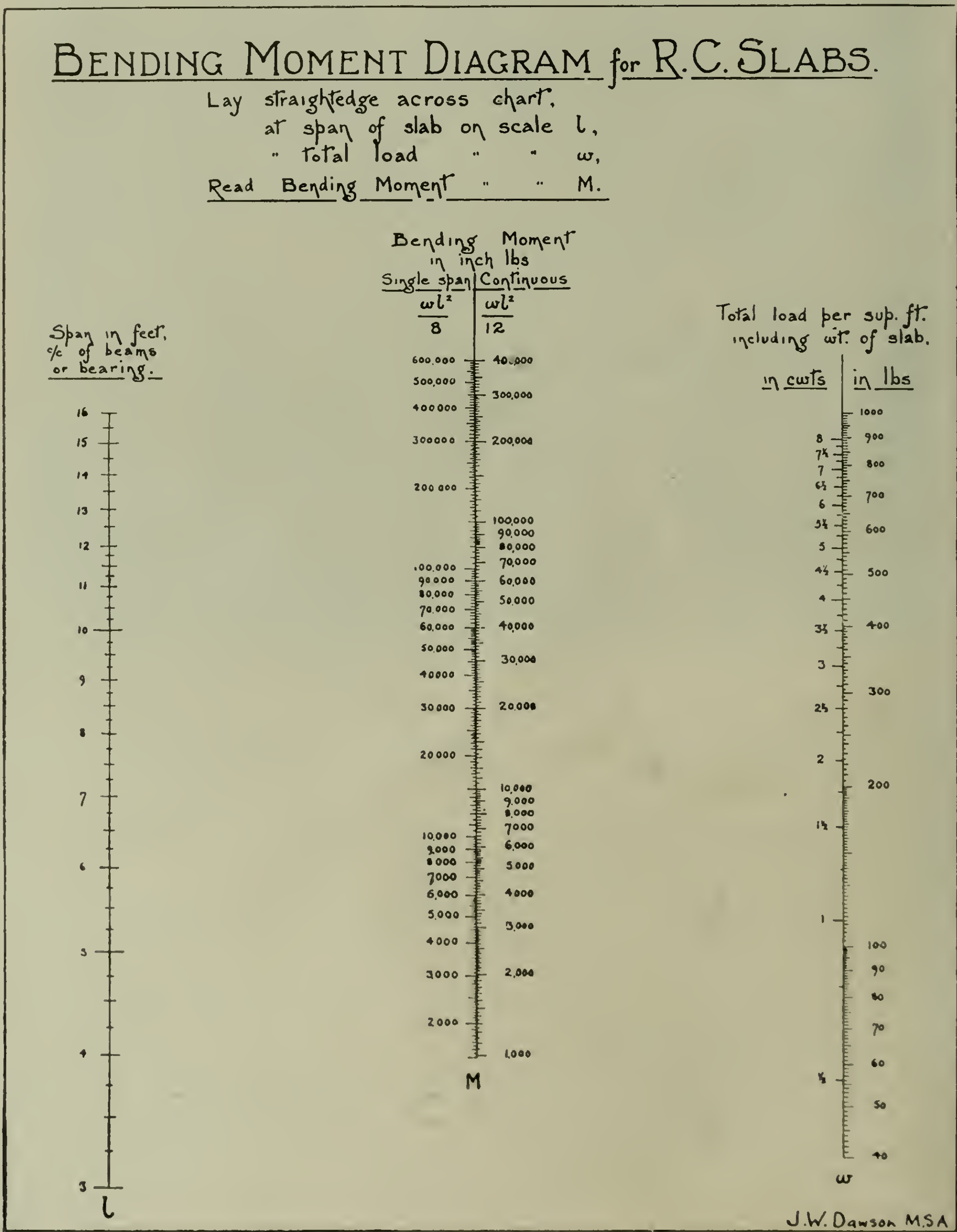
The preparation of the working drawings and supervision of the reinforced concrete was carried out by Messrs. Coignet, Ltd., Reinforced Concrete Engineers, 125, Gower Street, London, W.C.1.

GRAPHS AND ALIGNMENT CHARTS FOR THE DESIGN OF REINFORCED CONCRETE SLABS, BEAMS AND COLUMNS.—By JOSEPH W. DAWSON, M.S.A.

This set of graphs and charts has been prepared with the aim of eliminating as far as possible the laborious calculation usually involved in the designing of reinforced concrete construction.

It is not claimed for them that by their use reinforced concrete work can be thoroughly and exhaustively investigated. It is, however, claimed that in a few moments a beam, column or slab can be designed that will safely carry any reasonable given load in the most economical manner.

One other great advantage is, that in no case is it necessary to assume values which are uncertain before one can proceed to design. To design a tee-beam by using the formulæ approved by the Joint Committee, it is necessary to make assumptions which may prove to be wrong, necessitating the calculation being repeated, sometimes more than once.



The following are the working stresses allowed :—

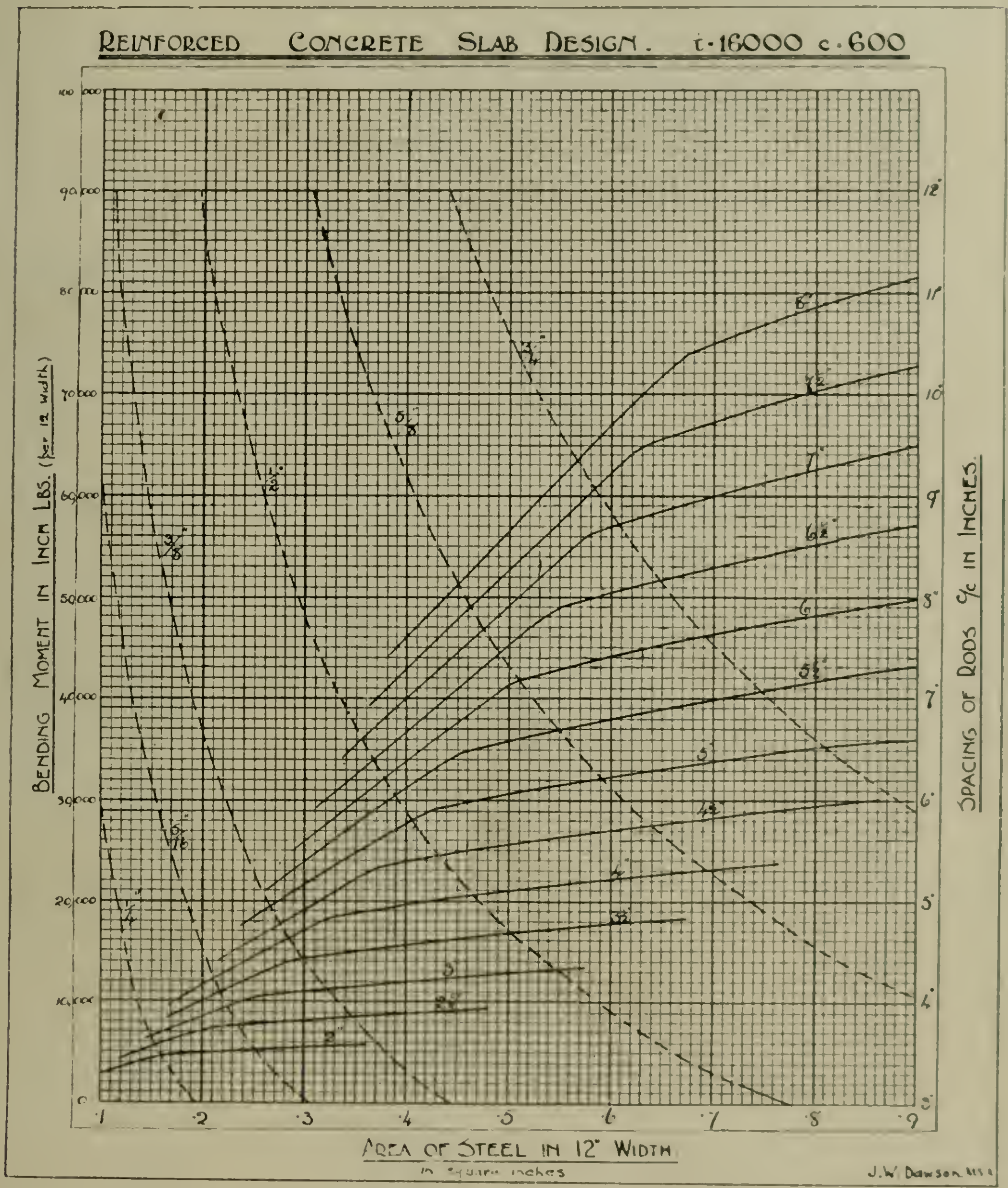
Concrete in compression in beams subjected to bending 600 lb. per sq. in.

Concrete in columns under simple compression—600 lb. per sq. in.

Steel in tension—16,000 lb. per sq. in.

Steel in compression—fifteen times the stress in the surrounding concrete.

The above working stresses are those recommended in the report of the Joint

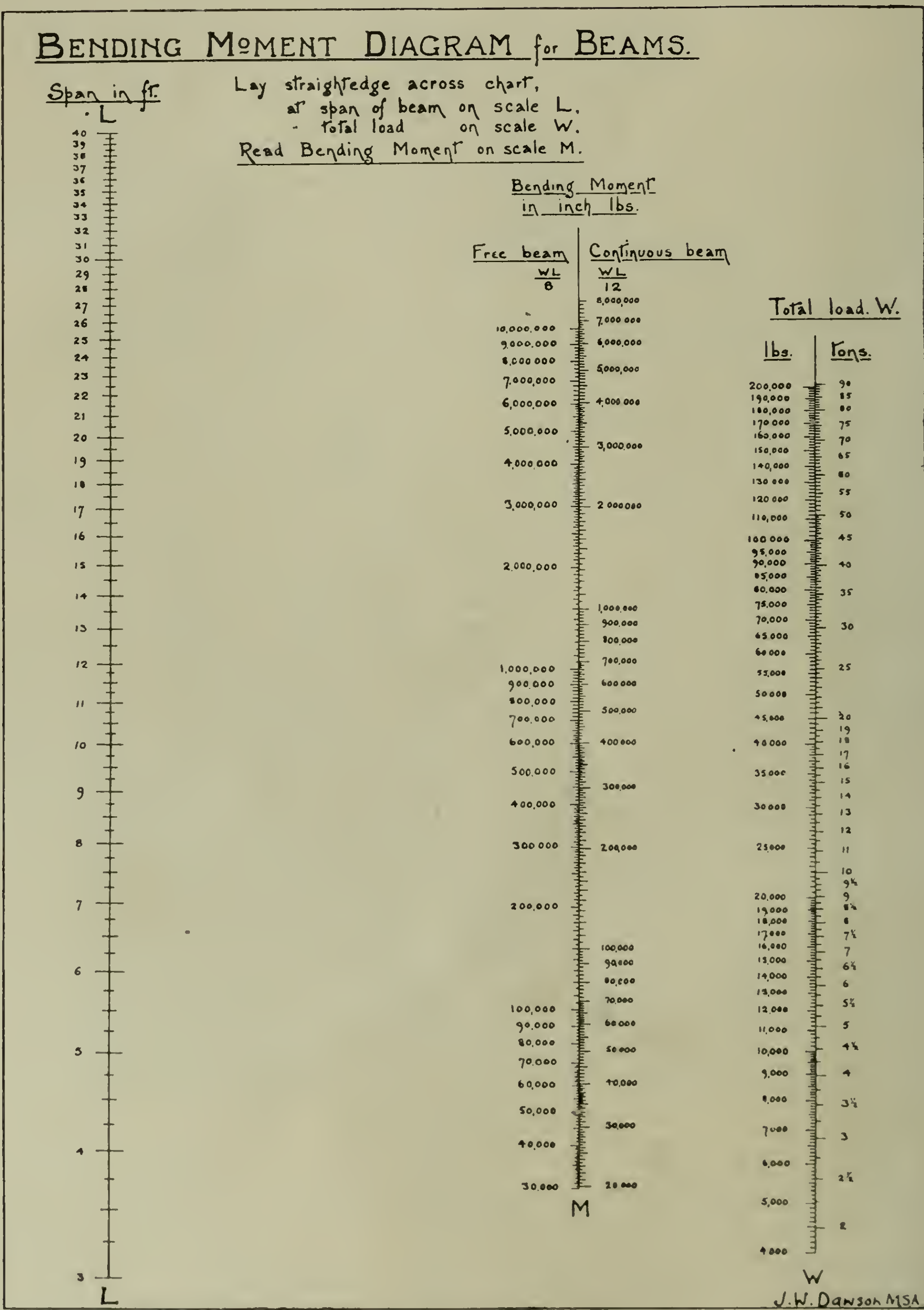


Committee on Reinforced Concrete. The charts and graphs are based on the recommendations and formulæ of this Committee.

(1) *Bending Moment Diagram for Reinforced Concrete Slabs.*—This is practically self-explanatory. The following points may be emphasised :—

(*a*) The total load per super foot is made up of the estimated super-imposed load, plus the weight of the floor slab itself. The weight of reinforced concrete is approximately 150 lb. per cu. ft.

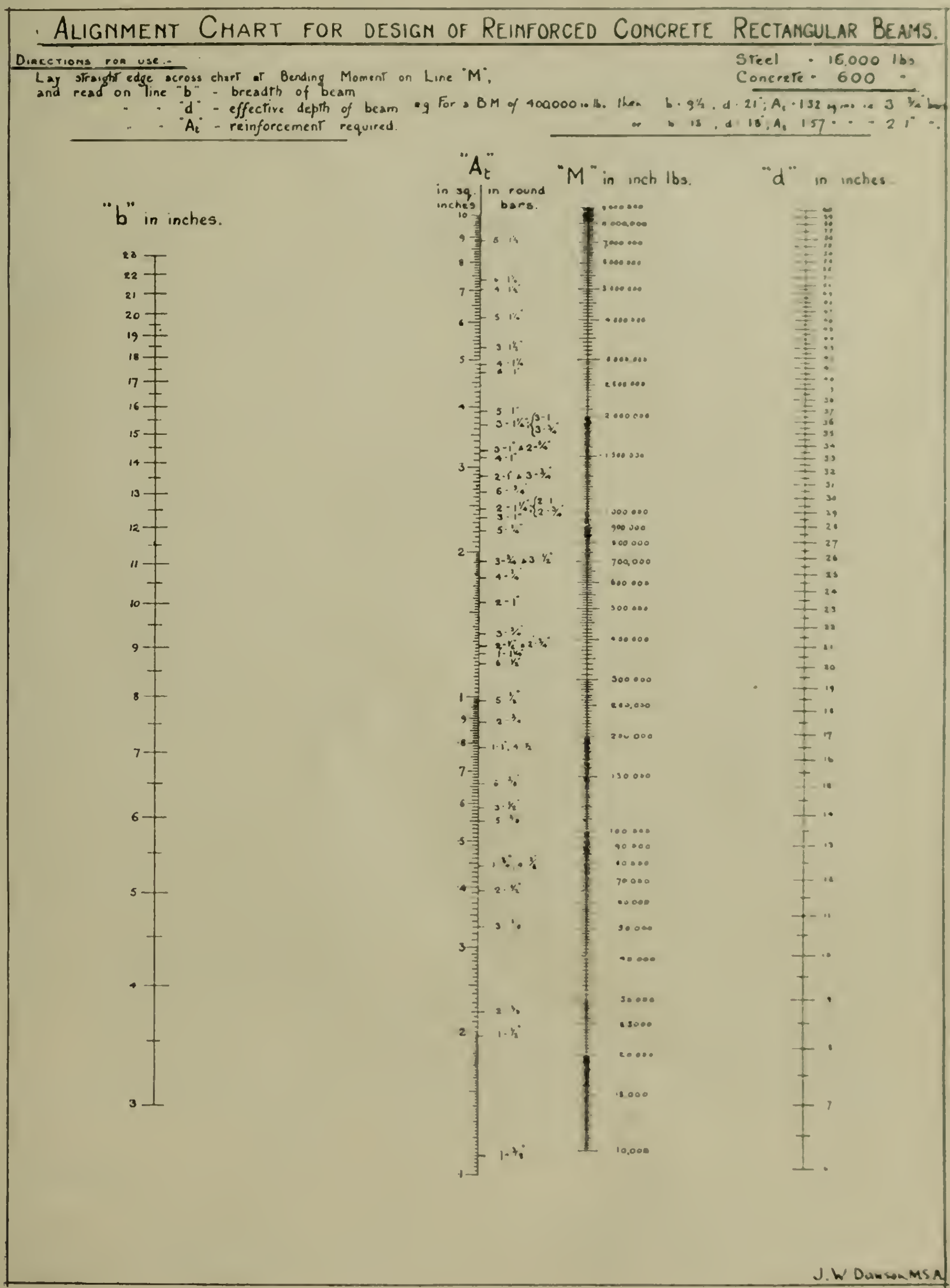
(*b*) For end spans, i.e. for a slab supported freely on a wall on one side and continuous over a beam on the other side, the Bending Moment formulæ may be taken as $\frac{wl^2}{10}$. To obtain this value add 20 per cent. to the value for $\frac{wl^2}{12}$, or subtract 20 per cent. from the value for $\frac{wl^2}{8}$.



The Bending Moment obtained is for a 12 in. width of slab.

(2) *Graph for the Design of Reinforced Concrete Slabs.*—From the value of the bending moment on the left-hand side of the graph, take a horizontal line cutting the full curved lines which indicate depths of slabs. Vertical lines from the points

where these lines are cut to the bottom line of the graph will give the areas in square inches of steel reinforcement per 12 in. width of slab, for each thickness of slab. The slab depth should be chosen which is cut near to the point where the direction of the line changes. This is the most economical. The slab depths shown are the effective depths, i.e. from the top of the slab to the centre of the reinforcement. To this



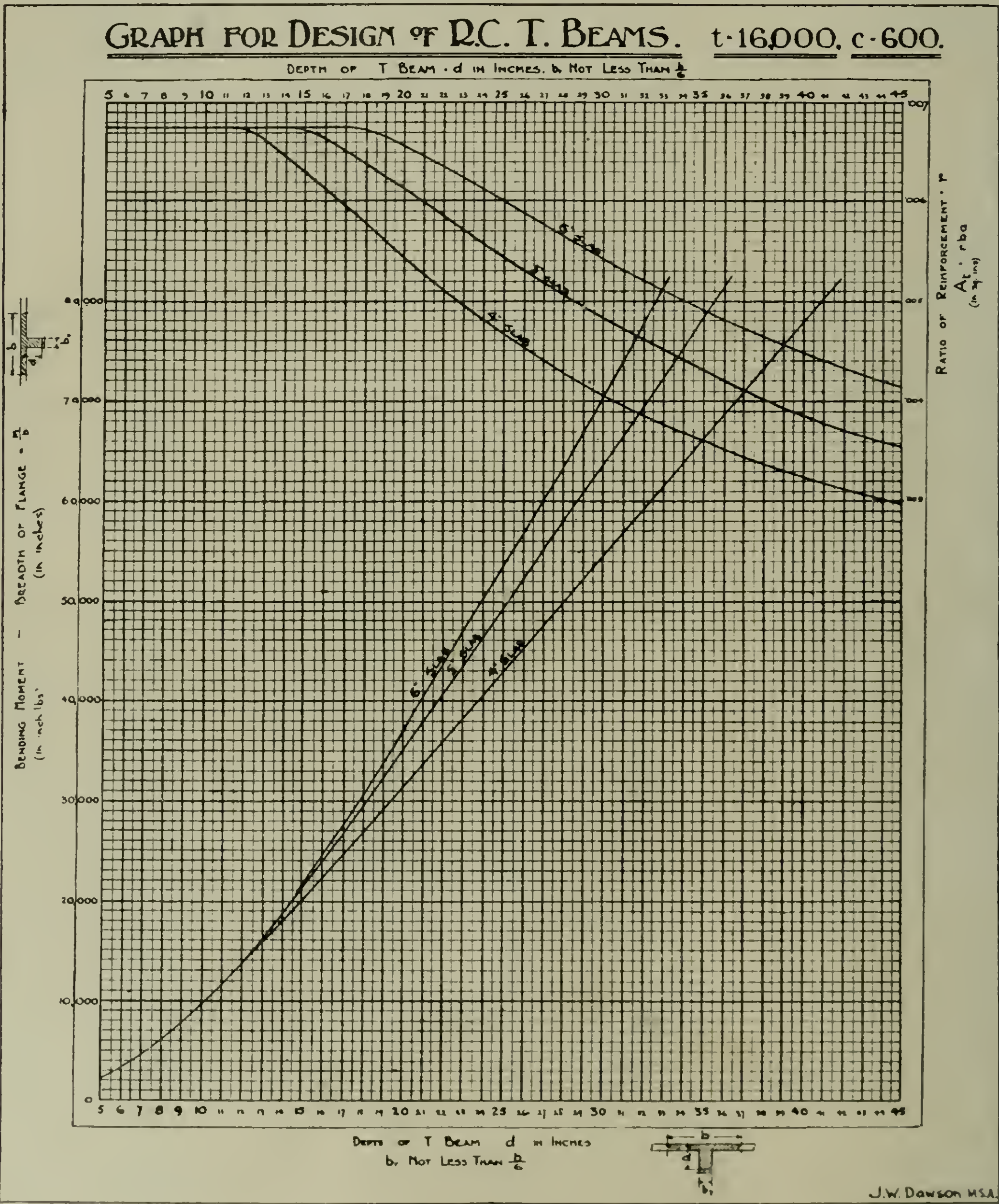
depth must be added sufficient concrete to provide for at least ½ in. of concrete protection to the reinforcement.

A line taken vertically from the area of steel in 12 in. width to one of the curved dotted lines, and then horizontally to the line on the right, will give the spacing of rods of the diameter indicated on the dotted line. *Example* :—

It is required to design a reinforced concrete slab to resist a bending moment of 30,000 in. lb.

It will be seen from the graph that a $6\frac{1}{2}$ in. slab would require ·32 sq. in. of steel in a 12 in. width; a 6 in. slab ·35 sq. in.; a $5\frac{1}{2}$ in. slab ·38 sq. in.; a 5 in. slab ·47 sq. in.; and a $4\frac{1}{2}$ in. slab ·85 sq. in.

If we take the $5\frac{1}{2}$ in. slab with ·38 sq. in. of steel, per 12 in. width, we must increase



the depth of slab to $6\frac{1}{2}$ in. to protect the reinforcement. From the graph we find that ·38 sq. in. of steel per 12 in. width is provided for by $\frac{1}{2}$ in. diameter round rods 6 in. apart.

(3) *Bending Moment Diagram for Beams.*—This is similar to the bending moment diagrams for reinforced concrete slabs, and the same remarks apply.

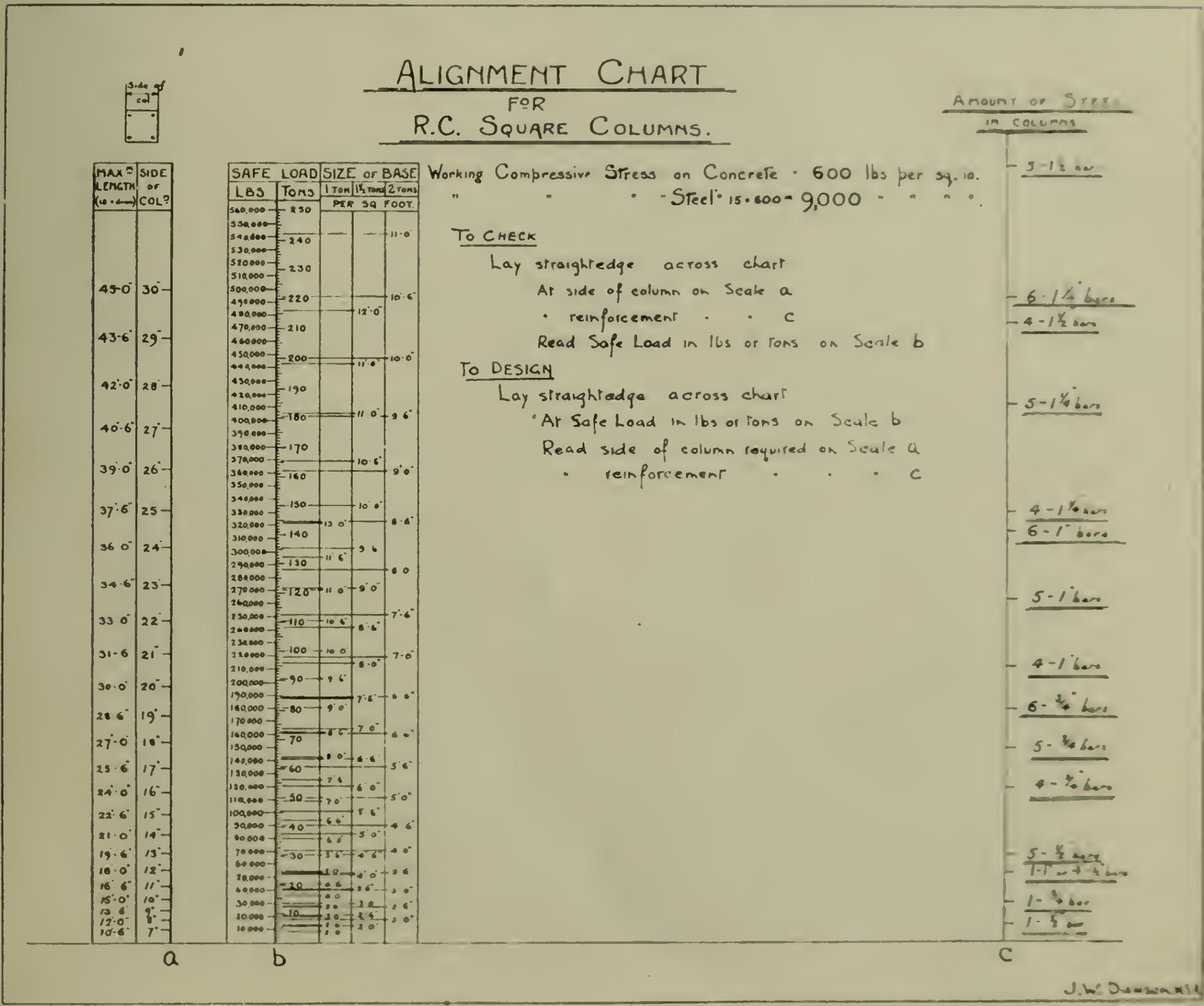
(4) *Alignment Chart for the Design of Reinforced Concrete Rectangular Beams.*—This is also self-explanatory, but attention is called to the following points:—

(*a*) The depth given is the effective depth, i.e. from the top of the beam to the centre of the reinforcement, and sufficient concrete must be added to provide at least 1 in. of concrete below the reinforcement.

(*b*) Shear reinforcement will be required if the beam has not sufficient cross area to take half the total load at 60 lb. per sq. in. of cross area, i.e. a 20 in. × 12 in. beam is safe so long as the total load does not exceed 28,800 lb.

(5) *Graph for Design of Reinforced Concrete* T *Beams.*—First, the bending moment in lb. in. (M) of the beam must be calculated. Then decide the width of slab in inches (b) acting with the beam.

This latter must not be greater than one-third the span of the beam, or more than three-fourths of the distance from centre to centre of the reinforcing ribs, or more



than fifteen times the thickness of the slab. Divide M by b, and from the value thus obtained, on the left-hand side of graph, take a horizontal line to the one of the lower curved lines marked with the full slab depth decided upon, and a line from this point vertically downwards will give the depth of beam required. From the depth of beam take a line vertically to the one of the upper curved lines marked with the correct slab depth, and then horizontally to the ratio of reinforcement required (r).

Area of reinforcement $= r \times b \times d$.

Example :—

To design a beam. Bending moment 1,500,000 in. lb. Breadth of flange, 50 in. Slab depth, 4 in.

$$\frac{M}{b} = \frac{1,500,000}{50} = 30,000$$

From the graph $d = 19\frac{1}{2}$ in.

Add $1\frac{1}{2}$ in. as protection to concrete, then depth of beam = 21 in. Breadth of rib not less than $\frac{50}{6}$ = say, 10 in.

Ratio of reinforcement = ·0055.

Area of reinforcement = ·0055 × 50 × 19·5 = 5·36 sq. in.

It is important to remember that shear reinforcement is necessary to all T beams.

(6) *Alignment Chart for Reinforced Concrete Square Columns.*—This chart is also self-explanatory. It is based on the formula $P = c[A + (m - 1)Av]$, where

A = the effective area of the column.

m = the modula ratio = 15.

Av = area of vertical reinforcement.

P = total safe pressure on column.

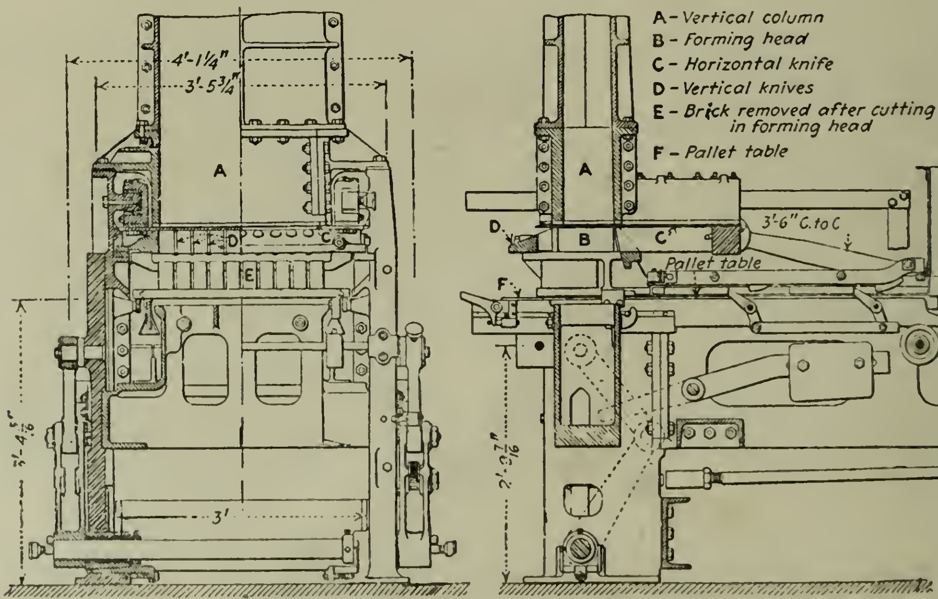
c = working stress on concrete—600 lb. per sq. in.

Reinforced concrete columns should be hooped with wire not less than $\frac{3}{16}$ in. diameter, and not more than 6 in. apart.

MEMORANDUM.

Concrete Bricks made without Forms.—Concrete brick made without forms is being produced commercially in Brooklyn, N.Y., by the Brooklyn Crozite Brick Corporation. The Company's plant has a capacity with its four brick machines of 100,000 bricks per day of eight hours.

In general design the brick machine is somewhat similar to a bulldozer, all parts being of substantial and rigid construction. Briefly, the essential parts of the machine



Details of Brick Machine, showing Essential Parts.

are as follows: An 8 ft. vertical column above the machine and leading from the mixer, whose cross-section is the width of ten standard-sized bricks and the length of one brick; a forming head upon which the column rests; a table or support carrying the pallets and which moves up and down so as to bring the pallets in contact with the bottom of the forming head, and again lowers them away from the forming head after the brick has been cut; a horizontal knife, $\frac{1}{2}$ in. thick, arranged to pass between the bottom of the column and the top of the forming head, thus cutting off a section of the concrete mass from the bottom of the column and retaining it within the forming

(*Continued on p.* 97.)

REINFORCED CONCRETE ROADS IN LEEDS.

By L. R. MOIR.

THE first reinforced concrete roads constructed by the Leeds Corporation were commenced in June, 1921.

As the work was part of a municipal scheme for the relief of unemployment, the use of labour-saving appliances was of necessity not entertained, and the entire reconstruction, comprising the surfacing of three thoroughfares—Burton Road, Garnet Road and Beza Street—was carried out with manual labour. The total area concreted was 9,600 super. yards.

The traffic using these roads is not dense in character, but has peculiarities

GARNET ROAD AFTER COMPLETION.

which required close study to ensure the success of the work. Along with the normal amount of motor and horse-drawn vehicles there is exceptionally heavy steam traction and trailer traffic from large engineering works in the neighbourhood. The loads carried have on occasion been as high as 25 tons, which, with the added weight of the vehicles, gives a total rolling load of 35 to 40 tons. The roadways previous to reconstruction were paved with Yorkshire Stone on a bed of ashes, and naturally, were quite inadequate to withstand this extraordinary traffic.

The new roadways, 6 in. in thickness, were formed of a 4½ in. bottom bed of 6 to 1 concrete, reinforced with steel wire mesh at a distance of 2 in. from the base ; on this bed was placed a 1½ in. layer of 3 to 1 concrete, which received from the tamping boards the ultimate conformation of the road surface. The aggregate used in the lower bed was 2 in. river gravel and sand; in the upper layer ½ in. whinstone, with sand and fine whinstone as fillers, was found to give very satisfactory results. The reinforcing mesh was B.R.C. Fabric No. 9, the longitudinal and transverse wires being 3 in. and 12 in. apart respectively. The weight of reinforcement was 4·71 lb. per sq. yard.

Each road was constructed in half widths, partly to avoid stoppage of traffic, and partly to obviate the use of excessively long and heavy tamping boards. The general routine of the work was as follows: The paving having been lifted, and the ground excavated to the required depth, reinforcement was placed in position, and wooden side and centre runners (3 in. by 2 in.) placed at correct heights for the tamping boards to work on. Concreting boards were worked on top of the mesh and on the adjoining footpath, being drawn back as the finished work approached them. The reinforcement was lifted into position through the

Garnet Road, Six Months after Completion.

first "throw" of bottom concrete by means of hooks. In order to ensure the homogeneity of the two layers of concrete, the working face of the upper layer was not allowed to be more than 6 ft. behind that of the lower bed, the foreman altering the board mixings to ensure this. All concrete was mixed as dry as possible. The tamping boards, curved to the required form of the road surface, and steel shod where they worked on the runners, were so utilised that the top of the concrete received a finely ribbed finish; no trowelling, except round gulleys and manhole covers, was permitted.

The new surface, when set, was covered with an ample layer of sand, and regularly watered for a fortnight. After a period of twenty-eight days the surface was tar-sprayed and covered with a fine layer of whinstone chippings, before being opened to vehicular traffic.

It has been mentioned that the normal thickness of the concrete was 6 in., but in several instances local conditions rendered a greater depth necessary. At the right angle junction of Garnet and Burton Roads 9 in. of concrete was laid so as to withstand any extra stress induced by the turning action of heavy loads;

also around all manhole covers an extra 3 in. was allowed ; at these, and around gulley grates, sub-surface reinforcement was introduced to absorb extra shock due to the impact of sudden loads.

Beza Street, Leeds, showing Half Width Construction and Projecting Reinforcement at Joint.

No expansion joints (either longitudinal or transverse) were introduced into the work, as it was considered after experiment that any utility which these features possessed was more than counter-balanced by their disadvantages. By

Beza Street, showing Effect of Traffic on experimentally Tar-sprayed Surface.

the insertion of extra strips of reinforcement at the end of each day's work, a good bond with the fresh concrete was ensured.

When considering the cost of these works it must be borne in mind that the gangs, working on the alternate week system, were chosen at random from the ranks of the unemployed, and that many of the men had to be instructed in the elements of navvying before proving themselves of much service. The average cost, inclusive of excavation, concreting, tar-spraying, haulage, materials, watching and administration charges, was approximately 23*s*. per super. yard.

The engineer approaching the question of estimating costs for the construction of reinforced concrete road by manual labour may be well advised to give the subject careful consideration. In the writer's opinion, the following natural conditions tend to increase the constructional cost (all outside factors being equal): variation in width, curves, works entrances, lack of appreciable gradient, excessive crown on, and bad foundation under roadway to be reconstructed, impracticability of closing road to traffic. Each of these conditions brings its own delays and difficulties, which have to be surmounted. Each, therefore, should be weighed and accounted for, in fixing the final estimated cost.

Burton Road—after Completion.

The construction of these roadways in the summer months presents no extraordinary difficulties. The effect of heat alone on the freshly laid surface can be minimised by the use of awnings, and by covering with sand as soon as the top has set. The combined action of sun and wind on freshly laid concrete must, however, be carefully watched. Successful work in the uncertain and variable English winter is a more intricate problem. Much has yet to be discovered in regard to the behaviour of large masses of concrete, comparatively thin in section when exposed in an immature condition to the action of frost, rain, and other agencies. After experience in laying some 25,000 square yards of concrete road surface in the autumn and winter months (in addition to the works under review), it is the writer's belief that, under such conditions, the treatment of the new road surfaces must be materially altered if the work is to be successful. Briefly, the finished work should be kept scrupulously clean, especially if traffic is allowed to use the half-road widths already completed; the object of this is to prevent disintegration of the surface owing to the grinding effect of mud and grit, and also to give the whole mass opportunity to dry out under the action of wind. Even although there may be periods of much rainfall, each drying interval adds to the hardness and strength of the roadway, and any temporary protection, such as is used in summer work, seems to retard this process.

A section of roadway may be affected by frost even if low temperatures occur 48 hours after the surface has hardened. If this happens it is preferable to let the damaged work rest for a week or so, as in many cases the frosted portion will harden under better weather conditions.

All tar-spraying and gritting should be deferred until late spring, or longer if possible. If done in winter the surfacing lifts in cakes and turns to mud, no matter how dry the concrete appears to be when it is applied.

The works described were carried out under the direction of Mr. J. B. Hamilton, City Commercial Manager, and Mr. E. W. Cockerlyne, Highways Engineer.

MEMORANDUM.

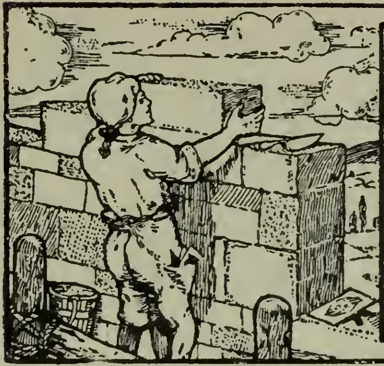
(*Continued from p.* 92).

head; nine vertical knives, each $\frac{1}{8}$ in. thick, attached to the horizontal knife and arranged to pass through the forming head, thus dividing the concrete previously cut off by the horizontal knife into ten bricks; the mechanical means for feeding empty pallets to the pallet table, and mechanical means for removing the pallets with their loads of brick after the forming of the bricks in the machine has been completed.

A considerable amount of experimental work was necessary before it was found possible to produce a concrete brick without forms, using the wet-mix method. A wide variety of aggregate was used as well as cement from various mills. Variation naturally occurred in the strength of test pieces made even with the same aggregate and cement from the same mill, but by varying, not more than one and one-half per cent. the amount of water used, practically equal results were secured. In the complete operation from the placing of the aggregate in the bins over the mixers until the bricks are stacked in the yards or shipped for use, materials including the finished bricks and the pallets are handled entirely mechanically.

With each stroke of the knife in the brick machine, the material deposited upon the pallet is divided into ten bricks. Each machine operates at the rate of 4,000 bricks per hour. The racks upon which the pallets with their bricks are deposited, while the setting of the concrete is taking place, are inclosed in a suitable building so as to protect the material from the weather and undue drafts, and so that uniform results may be obtained.

The natural colour of the product, as in all concrete, depends on the aggregate used and varies somewhat with different aggregate. For use as face brick a large variety of different colour effects may be obtained by adding to the aggregate in the mixer various mineral colours. In addition to this variation of colour a process has been worked out for applying facings of various materials to the bricks as they are removed from the brick machine and while the concrete is still wet, thus insuring a complete and proper bond between the body of the brick and the facing layer.



AMERICAN DOMESTIC ARCHITECTURE.

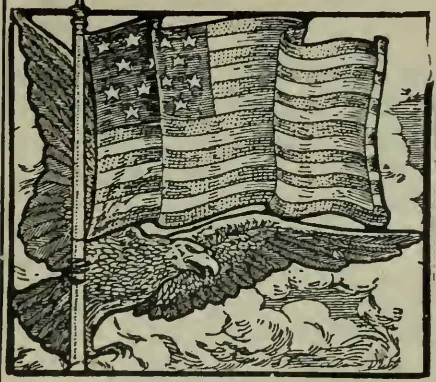
In the editorial pages of this issue will be found some reference to the recent exhibition of American architecture held at the R.I.B.A. and to American architecture generally. We speak there of the refinement that is a characteristic of much of the domestic work, such refinement being, we think, most pleasantly exemplified in the example of concrete construction which is given this month. Mr. Bertram Goodhue in the course of his address on American Architecture at the R.I.B.A. referred to the process of simplification that was taking place in houses both large and small ; here we have an excellent example of this process. Refinement and simplification have been noticeable qualities in all the examples of domestic work executed in concrete that have appeared in these pages. The simplification, in this case, may be very naturally accounted for by the method of construction, which is by means of concrete blocks treated with stucco finish. It is desirable, both in the interests of economy and sound construction, that the simple rectangular shape of the block be retained as far as possible.

The centre portion of this building is a very charming symmetrical composition. The large semi-circular bays, the three central French windows with their arched heads, and the first floor windows with their shutters, forming a broad frieze-like band, are in themselves simple enough elements, yet in their assembly much skill and restraint are displayed. The flanking bay trees, the window-boxes, and the fountain enhance the formality and complete the composition.

Much less successful is the treatment of the wings. The proportion of the masses to the voids is not satisfactory, and the somewhat attenuated lines, on the one side, and confusion, on the other, of the window and door frames inharmonious with the thin regularity of the glazing bars of the central portion. Nevertheless there is a pleasant quiet dignity about the whole, which we in England, recognising in it a free rendering of our own delightful eighteenth century work, cannot but admire. It is a design in the execution of which the concrete block can in every way be most suitably employed, indeed in the absence of a good building stone in the neighbourhood, it is, undoubtedly, the most practicable method of construction.

A CONCRETE BLOCK HOUSE WITH STUCCO FINISH AT LAKE FOREST, ILL., U.S.A.

Howard Shaw, Architect



STANDARD SPECIFICATIONS IN AMERICA.

(*Contributed.*)

The American Society for Testing Materials had its origin in the International Association for Testing Materials which aimed at securing international agreement upon the subject of standard tests of materials such as Portland cement. Although the International Association has been inactive since 1914, the American Society has been vigorous, and in the volume* of A.S.T.M. Standards—the second of a triennial series—just issued there are 160 standard specifications and methods of testing relating to metals, cement, lime, timber, road materials, etc.

The American Society for Testing Materials performs the duties undertaken in this country by the Engineering Standards Committee, and through its forty Standing Committees has formulated the standards already mentioned, promoting considerably the knowledge in general of the materials of engineering in so doing. An American Engineering Standards Committee also exists, but its functions are not constructive, and it acts as a bureau for collection, exchange and publication of information regarding standards.

The members of the standing committees of the A.S.T.M. are classified as "producers" and "non-producers" of the commodity they are dealing with and in general each committee is composed of equal numbers of each class. A useful feature of the procedure is the publication of "Tentative Standards" for the purpose of eliciting criticism, and final action towards the issue of a standard specification is not taken until the tentative standard has been before the public for a year or more, and due cognisance taken of any criticism of the same.

The British engineer will, of course, be governed by the standard specifications of his own country where such exist, and many of the American standards will be of academic interest only, but where there is no British standard, the A.S.T.M. standard will be valuable.

The standard specifications are, in many cases, supplemented by standard methods of testing and of chemical analysis, and the general adoption of such methods should assist in abolishing the tradition that agreement among expert testers and analysts is more the exception than the rule. Allowance is, however, still made for the personal factor by a system of "permissible variations" in analytical results; for example, in the determination of loss on ignition in Portland cement, "a permissible variation of 0·25 per cent. will be allowed, and all results in excess of the specified limit (4·0 per cent.) but within this permissible variation shall be reported as 4 per cent."

Among the standards of the A.S.T.M. are a few cases of "Recommended Practice," such as for annealing and case hardening of steel objects and notably one for "laying sewer pipe" which is useful as far as it goes, but unfortunately does not go into sufficient detail in connection with the cement jointing of the pipes. Standard "Recommended Practice" for pipe jointing, concrete mixing, treatment of concrete

* *A.S.T.M. Standards*, 1921. 890 pp. Published by American Society for Testing Materials, Philadelphia, Pa., price 10 dollars cloth, 11½ dollars half leather.

surfaces, etc., issued by committees of such a composition as to inspire confidence, would prove of great value in this country and undoubtedly tend to raise the standard of concrete work. It is somewhat tantalising to find that although the Americans have issued standards for such matters as determination of unit weight of concrete aggregate, moulding and storing test blocks of concrete in the field, etc., they have not tackled the more vital problems just mentioned.

A specification interesting to concrete men is that for cement grout. Although sand is regarded as an ingredient of the grout, the proportion is not specified but the fineness is required to be as follows :—

10 mesh sieve . . .	no residue.
20 ,, ,, . . .	not more than 20 per cent. residue.
200 ,, ,, . . .	not less than 95 per cent. residue.

The strength of a mortar containing three parts of the sand in question to one part of cement must be at least 75 per cent. of the strength developed by the same cement with three parts of standard sand mixed to the same consistency. In the sieve tests, the specification limits not only the thickness of the wire and the number of meshes per inch, but also the permissible variations in the number of apertures and the diameters thereof, thus deciding what is occasionally a vexed question in connection with the testing of cement for fineness.

The standard method of testing for the quantity of clay and silt in gravel or sand consists of elutriating a definite weight of the material with water in a pan 12 in. diameter, and 4 in. deep, until the wash water is clear, any material not settling in 15 seconds being regarded as clay and silt. The washed gravel or sand is dried and weighed to ascertain the loss of clay and silt, and the result is checked by evaporating the wash water to dryness and weighing the residue.

A standard method of test for toughness of rock, intended primarily for road stone, is of interest to cement manufacturers as it provides a means of comparing the relative difficulties of grinding the raw materials that are employed in cement manufacture. It might also serve for testing concrete. Toughness is defined as the resistance offered to fracture under impact, and the standard test consists of dropping a 2 kilogramme hammer on a steel plunger (1 kilo) with a spherical end resting on a cylindrical specimen (25 mm. × 25 mm.) of the rock to be tested. The drop of the hammer is commenced at one centimetre and increased by one centimetre at a time until the specimen fails. The height of the drop at which this occurs is the toughness of the specimen.

The Standard specification for concrete sewer pipe includes crushing test, hydrostatic pressure test and absorption test. The minimum crushing test for an 8 in. (internal) pipe is 1,430 lb. per lineal foot, being similar to the requirement for clay sewer pipe. An absorption up to 8 per cent. of the weight of the specimen tested is allowed, the absorption being ascertained by drying the specimen at 230° F., weighing, boiling in water for five hours and weighing again after removing superficial moisture. The hydrostatic test requires that the pipe shall stand a water pressure of 5 lb. per sq. in. for five minutes, 10 lb. per sq. in. for ten minutes, and 15 lb. per sq. in. for fifteen minutes without showing leakage, moisture appearing on the surface in the form of patches or beads not being considered leakage. These requirements are identical with those for clay sewer pipe and appear to constitute a standard that concrete could hardly fail to reach.

Standardisation is even applied to the procedure of fire-tests of materials and construction, the requirements covering time, temperature, load, size and pressure of water stream, and the conditions for the classification of " full protection " seem to be more severe than those adopted by the British Fire Prevention Committee. In view of the international character of fire insurance, this is one of the cases where international agreement is desirable on the question of standards.

Among the subjects to which American standards have been applied are methods of testing and analysis of paints, lubricants and bituminous materials for road treatment. The standard method of coal sampling and analysis is voluminous, the sampling portion being illustrated by thirty-four small sketches which make it plain to the novice how the operation is to be performed.

The era of national standard specifications is comparatively new, but it is proving of great benefit in several directions. The non-expert—be he farmer, house-builder or retailer—who desires to purchase structural materials without enlisting expert advice, has merely to require a guarantee of standard specification " material " to ensure that he is protected so far as quality is concerned. Again, the formulation of standards involves the setting up of committees of manufacturers, consumers and experts, and at the meetings of these committees the manufacturers learn what is expected of them in the matter of quality by those who are constantly employing their products, the individual manufacturers who may be lagging behind in quality appreciate the fact, and the experts who are perhaps inclined to be idealists learn the limitations of the manufacturers.

Finally, that standardisation does not mean stagnation is shown by the fact that in America, as in this country, standard specifications have been revised from time to time and usually with the result of providing an improvement in quality.

MEMORANDA.

Steel *v.* Concrete.—An interesting comparison of the relative cost of steel and concrete bridges is available in connection with the Tunkhannock Viaduct on the Lackawanna Railroad. The structure was built across a creek, 240 ft. above water level, and is nearly 3,000 ft. in length. Tenders were asked for a concrete bridge to the railroad company's design and also for a steel bridge to the company's or the contractor's own design. The tender for steel came to just over a million dollars ; capitalised, the cost of painting and maintenance amounted to $200,000 and the sinking fund to replace the bridge in 50 years, another $150,000. Thus the total was $1,350,000. The actual cost of the concrete viaduct, including extras, was $1,424,950. This included a strong parapet, and even if an engine broke through the parapet, it was not thought it would do as much damage as to a steel structure. Apparently no depreciation is allowed for the concrete viaduct. The structure, which is at least as handsome as a steel structure, has ten spans and is said to be quite satisfactory.

In considering the maintenance of steel bridges it is interesting to note that the Tower Bridge, London, is at present in the hands of workmen. For a period of six months a hundred men will be working day and night, repairing and repainting the steelwork. At least 100 tons of paint will be required and it is estimated that the total cost will approach £20,000.

Reinforced Concrete in Japan.—The Mitsui-Bussan building (illustrated on p. 137) is said to be the first four-storey structure in Yokohama to be built of reinforced concrete. The building has a comparatively heavy concrete frame better to withstand frequent earthquakes. The designing architect of the building is Mr. Otto Endo, Tokyo.

It is anticipated that it will soon be necessary to build fire resisting buildings and houses in Japan, owing to the increasing costs of timber. As there are as yet no building laws in Japan, houses can be built with double monolithic walls 9 in., 7 in., and 6 in. thick for the first, second and third storeys respectively. Such walls are reinforced with ⅜ in. rods spaced 24 in. on centres. The monolithic walls are preferred rather than walls of block, because of the frequent earthquakes.

A building law now in the course of preparation will be enforced in Japan in the near future, but it is expected to be favourable to the building of concrete structures, existing laws in America and Europe being followed.

THE CONCRETE INSTITUTE.

MONTHLY NOTES.

By the SECRETARY.

CONCRETE INSTITUTE JOURNAL.

The first number of the *Concrete Institute Journal* should by this time have reached every member. Members are reminded that they are invited to contribute short articles or letters on subjects of importance or interest to members of the Concrete Institute, which will be published from time to time as space may permit. Such articles and letters are not paid for and should not exceed, in the case of letters 200 words in length, and in the case of articles 1,000 words.

The Editor will also be pleased to receive the names of any members willing to undertake reviewing of books. Members willing to act as reviewers should state the type of book (e.g. Architectural Design, Structural Engineering, Concrete Ornament, etc., etc.).

All communications respecting the Journal should be addressed to the Editor, The Journal of the Concrete Institute, 296 Vauxhall Bridge Road, S.W.1.

MEETING IN FEBRUARY.

The 109th ordinary general meeting will take place at Denison House, 296 Vauxhall Bridge Road, S.W.1, on Thursday, February 23rd, 1922, when Mr. Kempton Dyson (member) will read a paper entitled: "What is the use of the Modular Ratio?"

CONCRETE AGGREGATES.—(*continued.*)

Note.—The publication of these lists commenced in the August issue, 1920, and was continued in the issues for September, November, December, 1920, and in March, April, May, June, July, August, September, December, 1921, and January, 1922.

The Concrete Institute takes no responsibility for the accuracy of the information supplied.

For footnote references, see September, 1920, issue.

Co. Leitrim.

The material used in Co. Leitrim for concrete aggregate is as a rule broken stone and sand.

Stone can be obtained almost everywhere, but sand is very scarce.

The screenings, usually limestone from County Council stonebreakers, are very much in demand for concrete work.

Maidenhead (a).

(1) *General description :* Thames Ballast.
(2) *Sources and locality of same :* River Thames in the reaches upon which the Borough has a frontage.
(3) *How obtained :* Dredging.
(4) *From whom obtained :* Conservators of the River Thames.
(5) *Is available quantity limited? If so, how?* Limited by the requirements of the Conservators for maintaining the navigation and flow of the River.

(6) *Present maximum output per day (stated in cubic yards) :* Apply for this to the Engineer.
(7) *Transport facilities :* To the Conservancy, Barge, Cartage and Mechanical Transport.
(8) *Is there any provision at or near source for washing or crushing ?* No.
(9) *Price per cubic yard, and where delivered :* 2*s.* 6*d.* in Barge alongside Banks, 1*s.* 6*d.* extra for landing same.
(10) *Is composition uniform ?* No.
(11) *Detailed description :—*
 (*a*) *Kind of stone or coarse material :* Gravel, flints, chalk.
 (*b*) *Kind of sand or fine material :* River sand.
 (*c*) *Relative proportions of coarse and fine material :* Proportions vary with each barge load.
 (*d*) *Shape of particles (rounded, angular, flat, etc.) :* Rounded, but the sand is sharp.
 (*e*) *Sizes of particles : approximate percentage that needs crushing to pass ¾ in. screen :* Average, perhaps 50 per cent.
 (*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* Mud and chalk.
(12) *Is sample sent with this sheet ?* No.
(13) *General remarks :* This material used with discretion and picked over for chalk makes an excellent aggregate.

Maidenhead (b).

(1) *General description :* Shingle.
(2) *Source and locality of same :* Gravel pits in various parts of the district.
(3) *How obtained :* Excavation and screening.
(4) *From whom obtained :* Owners of the pits.
(5) *Is available quantity limited ? If so, how ?* Limited by the small number of pits being worked at present.
(6) *Present maximum output per day (stated in cubic yards) :* Unknown.
(7) *Transport facilities :* Cartage or Mechanical Transport.
(8) *Is there any provision at or near source for washing or crushing ?* No.
(9) *Price per cubic yard, and where delivered :* 3*s.* 3*d.* to 3*s.* 6*d.* in the pits.
(10) *Is composition uniform ?* Practically so.
(11) *Detailed description :—*
 (*a*) *Kind of stone or coarse material :* Shingle.
 (*b*) *Kind of sand or fine material :* Pit sand.
 (*c*) *Shape of particles (rounded, angular, flat, etc.) :* Rounded. The shape and size of a broad bean.
 (*d*) *Size of particles ; approximate percentage that needs crushing to pass ¾ in. screen :* ¾ in. to 1 in. in length ; ½ in. to ¾ in. in breadth.
 (*e*) *Impurities present (as clay, sulphur, coal, organic matter) :* Clay.
(12) *Is sample sent with this sheet ?* No.

Maidenhead (c).

(1) *General description :* Pit and River Ballast.
(2) *Source and locality of same :* In River at Maidenhead.
(3) *How obtained :* Dredged from River or excavated at pits.
(4) *From whom obtained :* Thames Conservancy or owners of pits.
(5) *Is available quantity limited ? If so, how ?* Transport difficulties.
(6) *Present maximum output per day (stated in cubic yards) :* Impossible to state.
(7) *Transport facilities :* Motor or steam lorry.
(8) *Is there any provision at or near source for washing or crushing ?* No.
(9) *Price per cubic yard, and where delivered :* 2*s.* in barge (according to distance).
(10) *Is composition uniform ?* Fairly.

(11) *Detailed description :—*
 (*a*) *Kind of stone or coarse material :* Flint.
 (*b*) *Kind of sand or fine material :* Silicious.
 (*c*) *Relative proportions of coarse and fine material :* 1 sand, 2 flint.
 (*d*) *Shape of particles* (*rounded, angular, flat, etc.*) *:* Round, generally large.
 (*e*) *Size of particles ; approximate percentage that needs crushing to pass ¾ in. screen :* 3 in. to ¼ in.
 (*f*) *Impurities present* (*as clay, sulphur, coal, organic matter*) *:* Clay, small portion.

(12) *Is sample sent with this sheet ?* No.

REINFORCED CONCRETE PIERS AND MARINE WORKS.

By W. NOBLE TWELVETREES, M.I.Mech.E., M.Soc.C.E. (France).

The following is an abstract from a paper read before the Concrete Institute on Thursday, December 15th, 1921 :—

WHILE mass concrete or large blocks of plain concrete may be advantageously employed in important works where the engineer finds solid rock or a firm stratum of earth capable of supporting heavy masses of concrete, it generally happens that alluvial soil is encountered in tidal rivers and estuaries. Therefore numerous wharves, jetties, piers and other marine structures have been built of iron, steel and timber, with the object of reducing as much as possible the imposition of useless weight upon strata of low bearing power. The inevitable corrosion of iron and steel and the decay of timber render these materials particularly unsuitable for employment in construction situated partly below and partly above water level, to say nothing of the injury caused to timber by destructive sea worms.

Reinforced concrete, when properly designed and carefully applied by experienced contractors, is free from these drawbacks. At the present prices of materials, it is probably little, if at all, more costly than timber, and the ultimate economy resulting from its exceptional strength, durability and fire-resisting properties, gives reinforced concrete a clear advantage over the other materials mentioned.

The economy and structural advantages of reinforced concrete having been demonstrated in this country by a number of pioneer works, the earliest example of which was a retaining bank constructed in 1897, interest was slowly awakened in this method of construction among dock and harbour authorities, and by the end of 1906 many maritime structures had been completed in the West and South of England, on the Thames and the Tyne, and in Scottish and Irish seaports.

QUAYS, WHARVES, JETTIES AND PIERS.

As originally designed, reinforced concrete quays, wharves, jetties and piers were founded on piles driven into the bed of the sea, harbour, or river, the top of each pile being trimmed off a little above low water level. Pillars were then carried up to deck level in continuation of the piles, being braced by horizontal and diagonal members, and connected with the longitudinal and transverse beams and continuous slab constituting the decking. Although satisfactory in places where the depth of water is comparatively small, this type of construction is apt to be somewhat lacking in rigidity, owing to the absence of subaqueous bracing between the piles, in situations where there is a considerable depth of water at low tide.

This objection was overcome by the cylinder pier system patented by the late Mr. L. G. Mouchel. Each pier is formed by driving a group of piles into the bed of a river or harbour, sinking a cylindrical shell over the projecting portions, and filling the interior with concrete, suitably reinforced. The shell, usually ranging from 3 ft. to 6 ft. in diameter, is precast in sections of convenient length, the bottom section being provided with a cutting edge enabling it to penetrate into the soil. The sections are reinforced with longitudinal and circumferential rods, and the edges are moulded so as to form socket and spigot joints. Such piers possess great strength rigidity and stability, and have been used with much advantage in the construction of many piers and wharves for the accommodation of large steamships.

A further advance is represented by the method introduced by Messrs. Mouchel & Partners wherein precast units are applied to the construction of subaqueous bracing for structures formed either with piles or with cylinder piers. In cases where this form of bracing is adopted in conjunction with cylinder piers, triangular frames are moulded on predetermined sections of the shells, the outer end of the frames being afterwards cemented into recesses formed in adjacent piers or elsewhere.

A fourth method of construction, particularly suited to exceptionally massive piers or jetties, is one embodying the use of large caissons, capable of being floated into position, sunk on prepared beds, and afterwards filled up with stone or rough concrete.

The author then went on to give short descriptions of a large number of piers, wharves and jetties, and he also showed illustrations of them.

Referring to the coaling wharves and jetties at King's Dock, Swansea, he said a somewhat unusual feature in the general design of the coaling arm of the King's Dock, is the adoption of projecting jetties, whereby the quay accommodation has been very largely increased. On the north side a frontage of 1,000 ft. is occupied by the Great Western Railway coaling wharf and coal tip jetties, the latter being served by reinforced concrete viaducts ; and on the south side a frontage of 1,790 ft. has been occupied by the Midland Railway wharf, tip jetty and viaduct, and by two coal tip jetties and viaducts constructed for the Swansea Harbour Trust.

The wharves and jetties are of exceptional strength and solidity, and rise to a height of 41 ft. above the dock bottom. It was originally intended to build them in ordinary masonry, and the scheme then prepared embodied a series of longitudinal arches, extending some 60 ft. back from the quay front. Owing to the uncertain nature of the subsoil the cost of executing the works in this manner was found to be quite prohibitive, and the engineers came to the conclusion that reinforced concrete would be more economical, and at the same time more reliable than any other form of construction.

The wharves and jetties are of somewhat unusual design, and were constructed in a manner which is seldom possible in the case of dock and harbour work. Owing to the heavy loads involved by the employment of fixed and travelling coal hoists, the front portion of each structure was built up with massive pillars, 4 ft. 6 in. square and spaced 30 ft. 6 in. apart longitudinally, and as the work was executed before the admission of water into the new dock basin, these pillars and all parts of the work afterwards destined to be permanently submerged were constructed with the same facility as in the case of reinforced concrete land structures. The pillars in the front row are provided with extended bases of the usual type ; those in the second row having extended bases which are supported on groups of 14 in. square piles. The rear portion of each wharf and jetty is founded on piles continued up in the form of pillars 14 in. square in cross section. All these members are securely braced and completed by decking in the usual manner. The Great Western Railway wharf includes a traverser gantry 475 ft. long serving two travelling coal hoists running along the front, loaded trucks being transferred from the approach viaducts to the traverser and delivered thence to the hoists.

New Fish Dock, Fleetwood.—An interesting operation carried out by the Lancashire and Yorkshire Railway Company during recent years was the conversion of an existing timber pond at their Fleetwood Docks into a new dock for the fishing industry. An important part of this project was the construction of reinforced concrete quays along all four sides of the basin. The new quays are founded on piles driven into the ground at the bottom and along the margin of the dock, most of the quays consisting of trestles each including three piles and pillars, connected longitudinally by horizontal bracing and by the deck system of beams and slabs. The spaces between the front foundation piles were filled by sheet piling to form a watertight barrier. In addition to the resistance afforded by the monolithic nature of the construction, the stability of the quays is further assured by reinforced concrete land ties securely anchored to blocks of plain concrete embedded in the ground opposite every alternate trestle. Three sides of the new dock are provided with fish quays having an aggregate length of 1,860 ft., the fourth side being occupied by a coal quay, 680 ft. in length.

Oil Fuel Jetties.—One of the first oil pipe jetties designed for the supply of fuel to steamships is that which was constructed in 1911 at Gosport for the Admiralty. This jetty, built out across a bank of soft mud into deep water, is 981 ft. in length, by 25 ft. in width up to the head, which is 63 ft. 6 in. wide. Another oil jetty, constructed at Avonmouth Docks in 1918, embodies some interesting examples of precast bracings combined with ordinary reinforced concrete piles and other members. The latest example is the oil fuel island jetty built for the Anglo-American Oil Company at Brixham. The structural features of this jetty are at once interesting and unusual. Briefly described, the work consists of three strongly framed dolphins, rectangular in plan, connected by construction of the kind generally to be found in reinforced concrete wharves, and the whole connected by continuous decking, at a height of 10 ft. 6 in. above H.W.O.S.T., and 24 ft. above L.W.O.S.T. The front of the jetty is at a distance of 166 ft. from the harbour wall, and is 258 ft. in length. As the deck level is 51 ft. 6 in. above the bottom of the harbour, and in view of the heavy pull exerted on the bollards by ocean steamships of the largest size, the three main dolphins are of exceptionally powerful construction. They are founded on square piles driven in groups of five, each group being enclosed in a rectangular casing similar, except in shape, to the cylinders employed in Mouchel pier construction. The casings are 6 ft. 6 in. square, and in addition to being strongly braced in every direction, the solid piers are connected by precast slabs fitting into grooves and forming watertight partitions for the retention of rock filling. The square piers terminate 3 ft. above low water level and are finished by capping on which the superstructure was erected. The portions of the jetty between the dolphins are founded on 14 in. square piles, and in them, as well as in the superstructure over the dolphins, precast units have been freely employed. The oil pipe is laid on a cantilever platform along the back of the jetty, and is carried along a light approach viaduct to the shore, where it is connected with the oil reservoirs and pumps, the total length of the pipe line being more than 3,000 ft. The pipe is of 10-in. internal diameter, and is capable of delivering nearly 260 tons of oil an hour.

Quay Widening Works.—Another most useful application of reinforced concrete is in the execution of quay widenings. Many works of this class have been executed in the principal seaports of the United Kingdom, some embodying ordinary pile construction and others representing examples of cylinder pier construction. A simple but extremely useful example is to be found in Victoria Dock, Leith, where the south quay was originally formed from an old breakwater, the face of which sloped so that the deck of any vessel moored alongside was about 8 ft. from the edge of the quay. With the object of doing away with this serious inconvenience, the quay was widened and straightened by driving reinforced concrete piles in front of the old wall, bracing them by longitudinal walings and tying them back into the existing masonry, the ties near quay level being connected with concrete anchor blocks spaced 3 ft. apart.

Caissons and Pontoons.

One of the most remarkable uses of reinforced concrete is that represented by the construction of floating structures of various kinds, including caissons, pontoons, floating docks, barges, sailing vessels, motor boats and sea-going steamships.

The subject of concrete shipbuilding has already been discussed at previous meetings of the Institute, and the author here confines attention to structures which, although capable of floating in water, are only intended to float while they are being transported to predetermined positions, where they are sunk and secured in place to form permanent construction, either partly or entirely below water level.

Probably the most interesting structure of the kind ever built in reinforced concrete is that known as the "Batterie des Maures," a large caisson which has now found a permanent resting place in the Bay of Hyères, on the Mediterranean, where it is employed by the firm of Schneider & Co. for testing torpedoes supplied to the French Government (described and illustrated in an early volume of this journal).

The stability of a work such as the Batterie des Maures constitutes a difficult problem, for it is practically impossible to determine precisely the horizontal resultant of the forces due to the action of the waves in rough weather. Therefore, the monolithic nature of the reinforced concrete construction is a great advantage, as the walls and other parts are thoroughly consolidated and rendered capable of withstanding forces which might cause injury to a structure built in accordance with ordinary methods. So far as stability is concerned, it may be pointed out that an ample assurance of safety is provided by the fact that while the total weight of the battery is 9,000 metric tons, the weight of water displaced is only 3,700 metric tons, leaving a net weight of 5,300 metric tons. Further, it is stated that the structure is capable of offering 50 per cent. more resistance to over-turning moment than the maximum resistance for which provision need be made anywhere on the coast of the Mediterranean.

Two other examples of caisson construction in pier and kindred works were also described, namely, those used in a 100 metres long jetty at Alexandria, in Egypt, and the caisson or pontoon in connection with the slipways laid down originally for concrete shipbuilding at Barrow-in-Furness.

Slipways and Shipbuilding Berths.

A considerable number of works coming in this class have been executed in the United Kingdom, among them being the slipway for the Woolston floating bridge in Southampton Harbour; slipways at the shipyards of Messrs. J. S. White & Co., Ltd., Cowes, and Messrs. Cammell Laird & Co., Ltd., Birkenhead; shipbuilding berths for the Forth Shipbuilding Co., Ltd., at Alloa; and numerous slipways and berths in the yards which were so actively engaged in concrete barge and ship building during the war. Various ingenious methods of constructing building berths were adopted in the concrete shipyards, one which was found very satisfactory in practice embodying the construction of concrete foundations taking the form of a pathway following the outline of the vessel to be built, with a centre strip wide enough to carry the keel blocks, which, together with the bilge blocks, were moulded in advance with two pieces of pipe extending from side to side, so that the blocks could be readily handled by the aid of steel bars passed through the holes. The blocks were built up to the required height with bedding pieces of felt between successive blocks, oak wedges being placed on the uppermost blocks, and on the wedges were laid bearers for the timbering of the hull.

Landing Stages.

Since the construction in 1904 of the landing stage for mail tenders at Plymouth by the Great Western Railway Company, kindred structures have been executed in reinforced concrete at Southampton, Gosport, Chichester, Herne Bay, Newlyn and various other places. The most interesting of these landing stages is one at Clevedon for use by passenger steamers plying between that seaside resort and large centres of population on either side of the Bristol Channel (and described and illustrated in this journal some time ago).

Coast Protection Works.

The chief objection to the timber groynes which are so largely used in coast protection, is the perishable nature of the material. Within recent years, this objection has been entirely overcome by the adaptation of reinforced concrete to groyne design under the Owens and Case patent. The new type of groyne is of very simple character, consisting of grooved reinforced concrete pillars fixed in holes excavated in hard soil, or grooved reinforced concrete piles driven into soft soil, reinforced concrete slabs being dropped into place between the pillars or piles. The uprights, in either case, are made of sufficient height to allow additional slabs to be inserted as beach material accumulates, and where necessary raking struts are applied to ensure lateral stability.

When the beach has been built up to the required height, the groynes are completed by slabs rounded at the top to form a smooth coping along the entire structure.

Many groynes of this type have been built on the South Coast and elsewhere. The first cost is said to compare favourably with that of timber construction, while the ultimate cost is very much less, owing to the permanence of the material.

A similar method of employing reinforced concrete units has been applied to the construction of sea walls. An example is furnished by a sea wall in the Solent, near the entrance to Southampton Water, the new work taking the place of an old clay bank protected by timber sheet piles. Owing to the heavy annual cost of repairs, it was decided to replace the bank by a permanent wall of reinforced concrete. The latter consists of grooved pillars, 9 ft. long by 14 in. square, spaced 7 ft. apart, built up from concrete foundations, between them being reinforced concrete slabs 12 in. wide, and ranging from 14 in. to 6 in. in thickness. The slabs are placed in the grooves and grouted so as to form a perfectly water-tight wall. A reinforced concrete counterfort is attached to the head of each pillar, the lower end being terminated by a foundation block of plain concrete. The top of the wall is finished by a coping about 6 ft. above high water level.

Reinforced concrete retaining walls and sheet piling have been employed very extensively in protecting the banks of tidal rivers and other navigable channels, but it is scarcely necessary to occupy time by giving details of such works. It may be of interest, however, to refer to the case of a sheet pile which was exhibited a few years ago by Mr. W. J. Taylor, the county surveyor of Hampshire, after having been exposed to the action of tidal waters for a period of some fourteen years. Having been drawn and carefully examined, both the concrete and the steel were found to be in good condition, the steel being perfectly free from any trace of corrosion.

While dealing with coast protection works, reference may appropriately be made to the reinforced concrete breakwater built by the Irish Board of Public Works to protect the fishing harbour of Passage East, near Waterford. So far as the author is aware, this is the only example of a breakwater in the United Kingdom. The structure is 120 ft. long by 20 ft. wide, the sides being parallel for a length of about 80 ft., then converging to a point at each end. If this breakwater had to be constructed in the present day, it would probably be formed by sinking a caisson similar to those described in connection with the jetty in Alexandria Harbour. At the time when the breakwater was built, reinforced concrete engineers had not the advantage of possessing the extended experience which has since been gained as to the possibilities of caissons and other structures capable of being floated, and the breakwater was constructed as briefly described below. The substructure consists of a coffer-dam formed by driving sheet piles around the site, the whole being grouted to form a water-tight wall. The piles varied in length between 15 ft. and 30 ft., according to depth of the harbour bed, and the top of the coffer-dam was 3 ft. above low water level. The interior was filled with stone and rough concrete to give the requisite stability to the coffer-dam, on the top of which was built a superstructure consisting of reinforced concrete pillars, walls, horizontal and diagonal bracing, longitudinal and transverse beams, and a continuous deck slab, the whole in monolithic connection.

An important example of coast protection work is represented by the promenade extension at Burnham, in Somersetshire, the total length of the extension being 1,500 ft., and its width 20 ft. from the roadway to the inside of the parapet. The original designs provided for cast-iron columns, steel beams and reinforced concrete decking, but it was afterwards decided to execute the whole in the last-mentioned material.

The promenade decking consists of a continuous slab 4 in. thick, carried on beams spaced 5 ft. apart, the latter supported at the landward end by a concrete wall, and at the seaward end by a continuous beam carried by pillars, 10 in. square, spaced 15 ft. apart, and terminated by extended bases which are founded on solid concrete blocks. In each panel of the deck slab an opening 3 ft. 6 in. long by 1 ft. 6 in. wide is formed, protected by a grating, these openings being intended to permit the free escape of water and compressed air in rough weather. The sea front of the promenade is finished by a parapet 2 ft. high by 3½ in. thick, with a coping 12 in. wide, this parapet being capable of acting with the continuous beam below the two members forming a girder 3 ft. 2 in. in depth.

Constructed in 1911, the promenade was most severely tested by the high tides and heavy gales of March, 1914, when the strength and stability of the work undoubtedly saved the town from a serious inundation, such as that which occurred in 1910 before the execution of the protection work. In addition to enduring the tremendous force of the waves, the promenade was subjected to severe battering from fencing timbers and wooden seats that had been washed into the sea, and consequently suffered strains of far greater magnitude and much more trying character than those contemplated by the designers.

DISCUSSION.

Mr. C. H. Colson, in moving a vote of thanks to the author for his interesting paper, said he had had some considerable experience with reinforced concrete jetties. When jetties of this material were first built, there were nothing but steel or timber jetties. It was not, therefore, a question of whether reinforced concrete was going to be an absolutely permanent material, but of the extent to which its life would vary from that of the other materials. Since that time reinforced concrete has given its supporters many bad half hours, but it has justified itself. The main difficulty to be faced was the fact of a solid material with, embedded in it, another material which might expand; every precaution also needs to be taken to prevent that material from corroding. In many cases there was not sufficient cover left to the steel to really prevent its corroding. He did not in this remark refer to the first jetties, because he remembered very well that the first jetty that was built by his old friend Mr. Mouchel at Woolston was built with very great care. That had been more or less a show jetty, great care had been taken in preparing the material; and ten or twelve years after its construction he had seen the lengths of the piles lying down below the jetty, and, upon having some of these broken up, had found the steel quite as good as on the day when it was put into the concrete. But that fact did not prove, to his mind, that it was correct to copy timber construction in reinforced concrete construction. In modern structures of reinforced concrete, bearing in mind the fact that we had to fight against corrosion, the members should be so shaped that the steel should be embedded as deeply as possible. That, he submitted to the meeting, could be best done by massing the members together, using large beams and cylindrical piles rather than a copy of the timber structure. Where the timber structure was copied, signs of cracks appeared at the angles of the piles where the reinforcement came nearest to the surface, and that tended to show that the circular or even octagonal form of pile was a better form than the square one; because in the square pile the angle was much more susceptible of damage than it was in the octagonal pile. The speaker, however, suggested that copies of timber structures should not be used, but instead large cylinders—with piles embedded in them no doubt—where we could keep the steel away from the action of the water. He was not sure that he quite agreed with Mr. Mouchel's reinforced concrete cylinders because in them the conditions that he had laid down were not quite followed out. There you had a steel structure quite close to the surface of the cylinders, and he would like to ask Mr. Noble Twelvetrees what the result had been of experience on those cylinders? Had corrosion shown? Or had damage occurred where ships happened to touch? Regarding reinforced concrete groynes, perhaps his experience had been rather unfortunate; but it tended to show that although these might be extremely useful in some cases, very great care was needed to see the conditions were really suitable for their use. He thought probably they would be very good on sandy or rocky beaches, but in the case of a shingle beach, the attrition of the shingle very rapidly wore away the concrete and exposed the steel structure.

Mr. S. Bylander, in seconding the vote of thanks, said Mr. Twelvetrees had emphasised the fact that reinforced concrete was a wonderful material, and that very little damage would result to a structure where it was used, from collisions or bad treatment. Any one who had tried to steer a ship, and place it next a jetty, would realise the enormous strain there was, and the bending of the piles or piers in the jetty. He remembered once trying to steer a ship near to a jetty which was of timber; and he thought the jetty must have moved very nearly a foot. On the point of the need for stability and strength, Mr. Twelvetrees had said in the early part of his paper how difficult it was to get braces below water level, and he (Mr. Bylander) would explain a method that he had recently seen employed for a bridge where there was very great depth of water, and where, for reasons of cost, it was not desirable to use caissons. Piles over 100 ft. long were made about 2 ft. 6 in. in diameter and hollow. These piles were made with exceptional care to ensure that the steel was properly protected. Concrete about 6 in. in thickness was used. The piles were made on the shore, and the upper end closed temporarily. The piles were then floated into position, raised by cranes placed on barges, lifted into the vertical position, and sunk by means of a water jet through a pipe inside the pile. In that manner the piles were sunk to a great distance into the sand and, after being placed in position at a satisfactory depth, another pipe was inserted into the hollow portion of the pile and the inside filled with cement grout; so that finally there was a solid concrete pile capable of resisting horizontal pressure as well as carrying the load.

Mr. W. J. H. Leverton, referring to the question of the suitability of reinforced concrete groynes, said if these were cast *in situ* they seemed to be quite useless unless they were protected from the waves for a very long time—which was impracticable.

Professor Matthews asked if it was a fact that owing to reinforced concrete piles often being bound to absorb the sea water into which they are driven, that engineers are now experimenting with all sorts of solutions to coat the piles before they are driven; and that one of the materials they have used for that purpose is tar? He said a certain dock engineer had had a trough of tar made, picked the pile up by a crane, dipped it into the tar and then drove it. He said he had broken open one of the piles treated in that way several weeks after, and found that the tar was doing its work well by preventing the absorption of the sea water.

Mr. Gardner said that Mr. Twelvetrees had made special reference in his paper to the bow-string bridge, one example being 60 ft. and the other 100 ft. long. That type of bridge seemed to be most suited for the reinforced concrete construction, being virtually an arch, and with not much work coming on the web system, but it would be interesting to know for what weights it was designed, the rolling loads, etc. With regard to the protection of the reinforcement, it seemed to him there was a difficulty; a thicker protection to the under side of beams and decking would bring with it a bigger crack.

MEMORANDUM.

Physical and Chemical Survey of the National Coal Resources.—The Fuel Research Board have made arrangements for the recognition of the Lancashire and Cheshire Coal Research Association as the local Committee working under the Board for the purpose of dealing with the physical and chemical survey of the coal seams in this area. The Chairman of the Committee is Mr. Robert Burrows, and the Director of Research Mr. F. S. Sinnatt.

TENTATIVE RECOMMENDED PRACTICE FOR THE CONSTRUCTION OF CONCRETE FUEL OIL STORAGE TANKS

PREPARED BY COMMITTEE ON CONCRETE STORAGE TANKS OF THE AMERICAN CONCRETE INSTITUTE.

In our last number we published a short article dealing with concrete oil storage tanks. In the following pages we are able to publish, by the courtesy of the American Concrete Institute and the Portland Cement Association, Chicago, a tentative specification for the good construction of such tanks, as well as some drawings, showing tanks of different dimensions.—Ed.

MATERIALS.

Cement.—The cement should meet the requirements of the current standard specifications for Portland cement adopted by the American Society for Testing Materials and this Institute (Standard No. 1). It should be stored in a weathertight structure with the floor raised not less than one foot from the ground. Cement that has hardened or partially set should not be used.

Aggregates.—Before delivery on the job, the contractor should submit to the engineer a 50-lb. sample of each of the aggregates proposed for use. These samples should be tested and, if found to pass the requirements of the specifications, similar material should be considered as acceptable for the work. In no case should aggregates containing frost or lumps of frozen material be used.

Fine Aggregate.—(*a*) Fine aggregate should consist of natural sand or screenings from hard, tough, crushed rock or pebbles consisting of quartz grains or other hard material clean and free from any surface film or coating and graded from fine to coarse particles, passing, when dry, a sieve having four meshes per linear inch. Fine aggregate should not contain injurious vegetable or other organic matter as indicated by the Colorimetric Test, nor more than 7 per cent. by volume of clay or loam. Field tests may be made by the engineer on fine aggregate as delivered at any time during the progress of the work. If there is more than 7 per cent. of clay or loam by volume in one hour's settlement after shaking in an excess of water, the material represented by the sample should be rejected.

(*b*) Briefly, the Colorimetric Test may be applied in the field as follows: Fill a 12-oz. graduated prescription bottle to the 4½-oz. mark with the sand to be tested. Add a 3 per cent. solution of sodium hydroxide until the volume of sand and solution, after shaking, amounts to 7 oz. Shake thoroughly and let stand for twenty-four hours. The sample should then show a practically colourless solution, or at most a solution not darker than straw colour.

Coarse Aggregate.—Coarse aggregate should consist of clean, hard, tough, crushed rock or pebbles graded in size, free from vegetable or other organic matter, and should contain no soft, flat or elongated particles. The size of the coarse aggregate should range from 1 in. down, not more than 5 per cent. passing a screen having four meshes per linear inch, and no intermediate sizes should be removed.

Mixed Aggregate.—Crusher-run stone, bank-run gravel or mixtures of fine and coarse aggregates prepared before delivery on the work should not be used, because the ratio of fine to coarse material varies so widely as to lead to concrete mixtures of greatly varying proportions.

Water.—The water should be free from oil, acid and injurious amounts of vegetable matter, alkali or other salts.

Reinforcement.—The reinforcing metal should meet the requirements of the current standard specifications for billet steel reinforcement of the American Society for Testing Materials, excepting that cold twisted square bars should not be employed in the construction. Reinforcing should be free from excessive rust, scale, paint or coatings of any character which would tend to reduce or destroy the bond.

PROPORTIONS.

Unit of Measure.—The unit of measure should be the cubic foot. Ninety-four pounds (one sack or one-fourth barrel) of cement should be assumed as 1 cubic ft.

Proportions.—The concrete should be mixed in the proportions by volume of one sack of Portland cement, $1\frac{1}{2}$ cubic ft. of fine aggregate and 3 cubic ft. of coarse aggregate.

MEASURING.—The method of measuring the materials for the concrete, including water, should be one which will ensure separate and uniform proportions of each of the materials at all times.

MIXING.

MACHINE MIXING.—(*a*) All concrete should be mixed by machine (except when under special conditions the engineer permits otherwise) in a batch mixer of an approved type equipped with suitable charging hopper, water storage and a water-measuring device which can be locked.

(*b*) The ingredients of the concrete should be mixed to the required consistency and the mixing continued not less than one and one-half minutes after all materials are in the mixer and before any part of the batch is discharged. The mixer should be completely emptied before receiving materials for the succeeding batch. The volume of the mixed material used per batch should not exceed the manufacturer's rated capacity of the drum.

(*c*) The mixing plant should be of sufficient capacity and power to carry out each pre-arranged operation without danger of delay during the process.

CONSISTENCY.—The quantity of water used in mixing should be the least that will produce a plastic or workable mixture which can be worked into the forms and around the reinforcement. Under no circumstances should the consistency of the concrete be such as to permit a separation of the coarse aggregate from the mortar in handling. An excess of water should not be permitted as it seriously affects the strength of the concrete, and any batch containing such an excess should be rejected.

RE-TEMPERING.—The retempering of mortar or concrete which has partially hardened, that is, remixing with or without additional materials or water, will not be permitted.

REINFORCEMENT.

PLACING.—Reinforcing steel should be cleaned of all mill and rust scales before being placed in the forms. All reinforcement should be bent or curved true to templates, placed in its proper position as required by the plans, and securely wired or fastened in place well in advance of the concreting. Reinforcement should be inspected and approved by the engineer before any concrete is deposited.

SPLICING.—Wherever it is necessary to splice the reinforcement, no lap-splice should be less than 40 diameters. No two laps of adjacent rods should be directly opposite each other in circular walls.

DEPOSITING.

GENERAL.—(*a*) Before beginning a run of concrete all hardened concrete or foreign material should be completely removed from the inner surfaces of all conveying equipments.

(*b*) Before depositing any concrete, all débris should be removed from the space to be occupied by the concrete, all steel reinforcing should be secured in its proper location, all forms should be thoroughly wetted, except in freezing weather, unless they have been previously oiled, and all formwork and steel reinforcing should be inspected and approved by the engineer.

HANDLING.—Concrete should be handled from the mixer to the place of final deposit as rapidly as possible and by methods of transporting which would prevent the separation of the ingredients. The concrete should be deposited directly into the forms as nearly as possible in its final position so as to avoid rehandling. The piling up of concrete material in the forms in such manner as to permit the escape of mortar from the coarser aggregate should not be permitted. Under no circumstances should concrete that has partially set be deposited in the work.

DEPOSITING.—(*a*) Where continuous placing of concrete in floor and walls is impracticable, the operations should be in the following order:

1. The concrete of footings and floor.
2. The concrete of walls.
3. The concrete of columns, if any.
4. The concrete of the roof.

(*b*) No break in time of over forty-five minutes should occur during any one operation except between columns and supported roof slabs, where six hours should elapse to permit the settlement of concrete in the columns. In placing concrete in floors, it should not be allowed to set upon exposed vertical faces where work is temporarily discontinued. Column footings should be placed monolithically with floor, and the floor reinforcement so designed as to distribute the column load over a sufficient area.

(*c*) In walls the concrete should be placed in layers of not over 12 in. for the entire wall so that a monolithic structure will result. The concrete should be thoroughly worked around the reinforcing material so as to completely surround and embed the same.

(*d*) If the placing of concrete is unavoidably interrupted by accident or otherwise, the previous surface should be roughened and washed clean with a hose, a mixture of 1 : 1 mortar slushed on uniformly before further concreting is done, and the new concrete deposited immediately thereafter.

(*e*) When deposited in the forms, concrete should be thoroughly spaded against the inner and outer faces of the forms so that it will densely compact and force out the trapped air and work back the coarser particles from the face of the forms. More and better work can be accomplished by using light wooden sticks, 1 by 2 in., planed smooth, with sheet blade at lower end, rather than with heavy spades. Enough labourers should be employed, spading *continuously*, to obtain satisfactory results.

Depositing Concrete during Freezing Weather.—(*a*) During freezing weather, the stone, sand or water or all three materials should be heated so that the concrete mixture will have a temperature of at least 60 degrees Fahrenheit. After concrete is deposited, precaution should be taken to prevent freezing for at least forty-eight hours. Concreting should not be begun when the temperature is below 35 degrees Fahrenheit.

(*b*) The tank should not be placed in service until after the engineer in charge of the work is assured that the concrete has gained sufficient strength to resist all involved stresses.

FINISHING.

The floor and roof should be brought to grade with a straight-edge or strike-board, finished with a wood float and troweled to a smooth surface as soon as possible after the concrete is deposited. Voids in walls, if any, should be filled with a 1 : 1½ mortar as soon as the forms are removed.

FORMS.

Material.—The forms should be of good material, planed to a uniform thickness and width, tongued and grooved for walls, strongly made and located or held in place by exterior bracing or on the outside of circular walls by circumferential bands so that no distortion allowing displacement of concrete is possible.

Workmanship.—Joints in forms should be tight so that no mortar will escape. If forms are to be re-used, they should be thoroughly cleaned; a slush mixture of one-half petrolatum and one-half kerosene makes a good mixture for oiling forms. The use of bolts or wires through the concrete should be prohibited.

Removal.—The forms should not be removed until the concrete has sufficiently hardened so that no deflection or damage will result. In warm weather column and wall forms should remain undisturbed for at least 48 hours and roof forms at least 7 days. In cold weather no predetermined rules can be made.

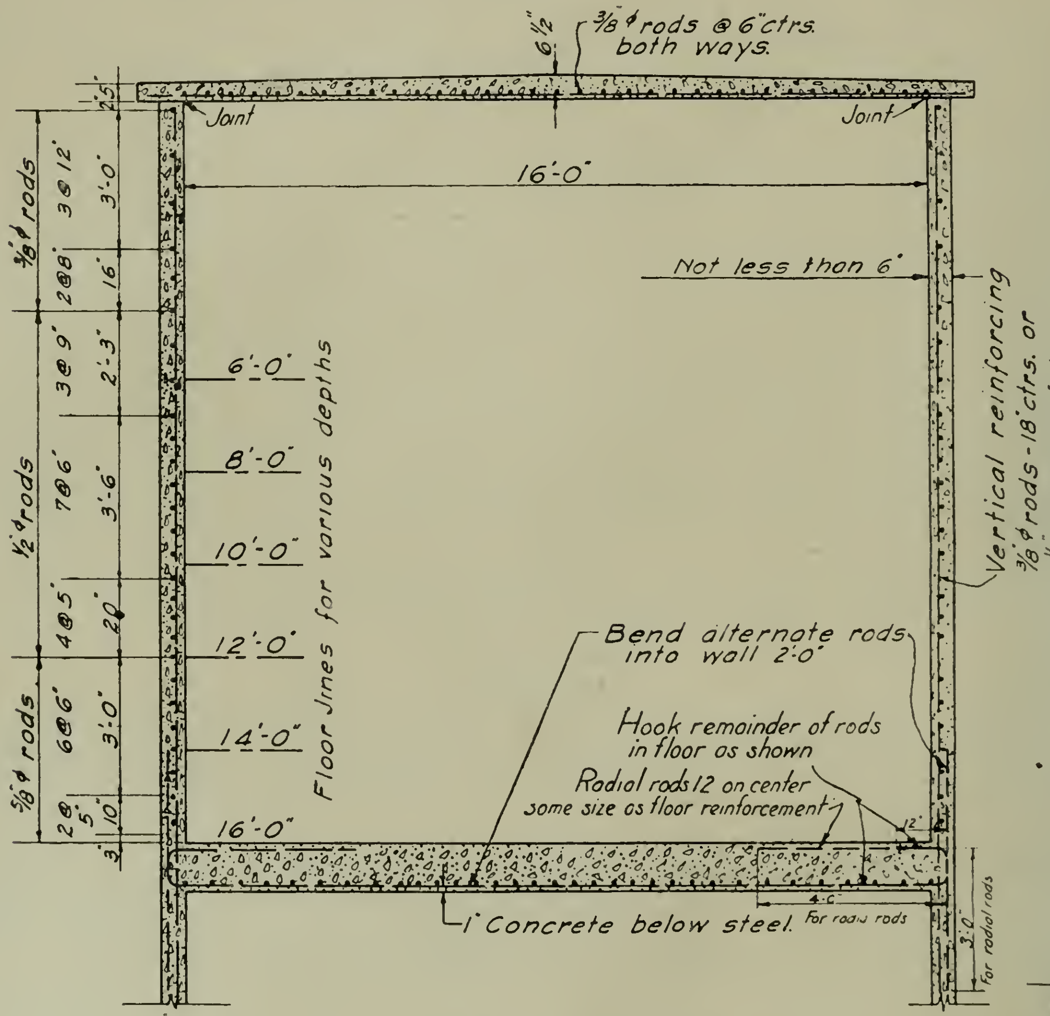
Sliding Forms.—Contractors equipped to handle the work with sliding forms may be permitted to do so provided the forms are left at one level until the concrete which will be exposed on raising them has hardened sufficiently to sustain the weight of the concrete above.

DETAILS OF CONSTRUCTION.

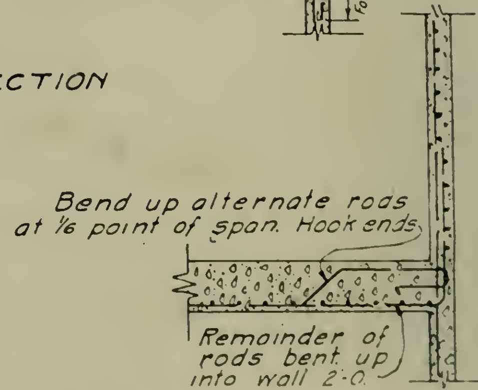
Joints.—Unless the roof is insulated against temperature changes by sufficient earth cover or the reinforcing in walls and roof is designed to take care of temperature stresses likely to occur, an expansion joint should be provided between the tops of walls and the bottom of roof slabs so that any expansion of the roof due to temperature will not transmit bending moment into the walls.

(*b*) In roof slabs where temporary stops are necessary they should be made on the plane of least shear, that is, at the middle of beams or slabs

(c) If walls and floor are not deposited in one operation an approved joint or dam should be provided between the floor and walls. It can be made as follows: (1) Provide a recess in the floor to engage the wall and insert a galvanised iron strip about 8 in. wide with joints soldered and riveted so as to form a continuous band on one side of the recess, or (2) place a 10-in. strip of de-formed sheet metal 1 in. back from



CROSS SECTION

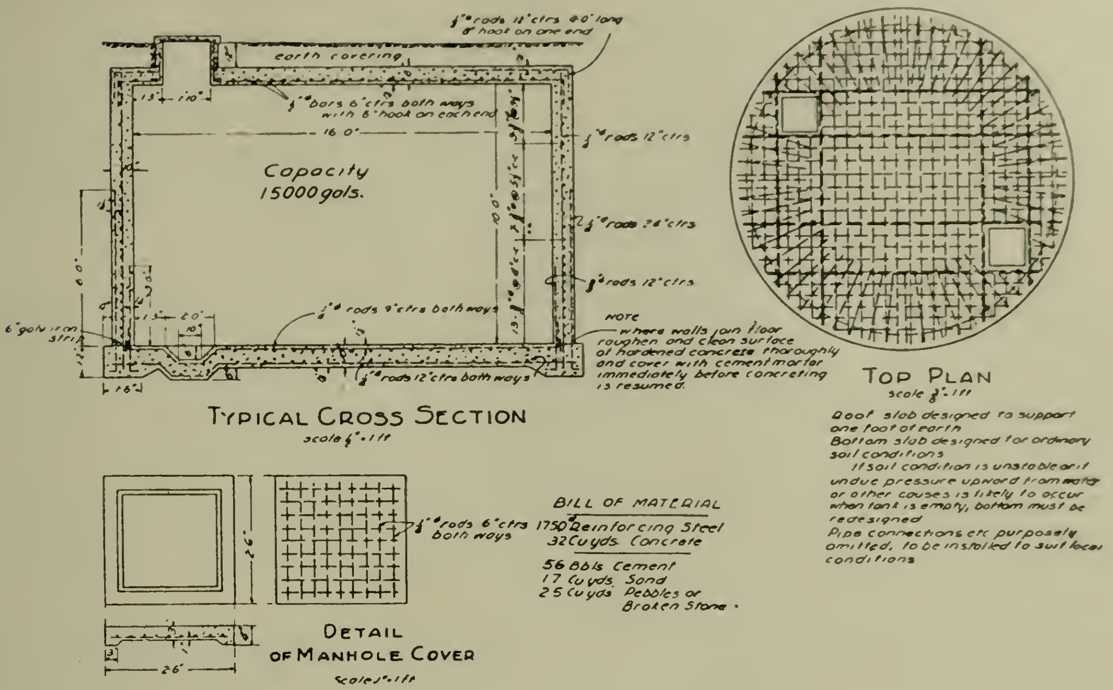


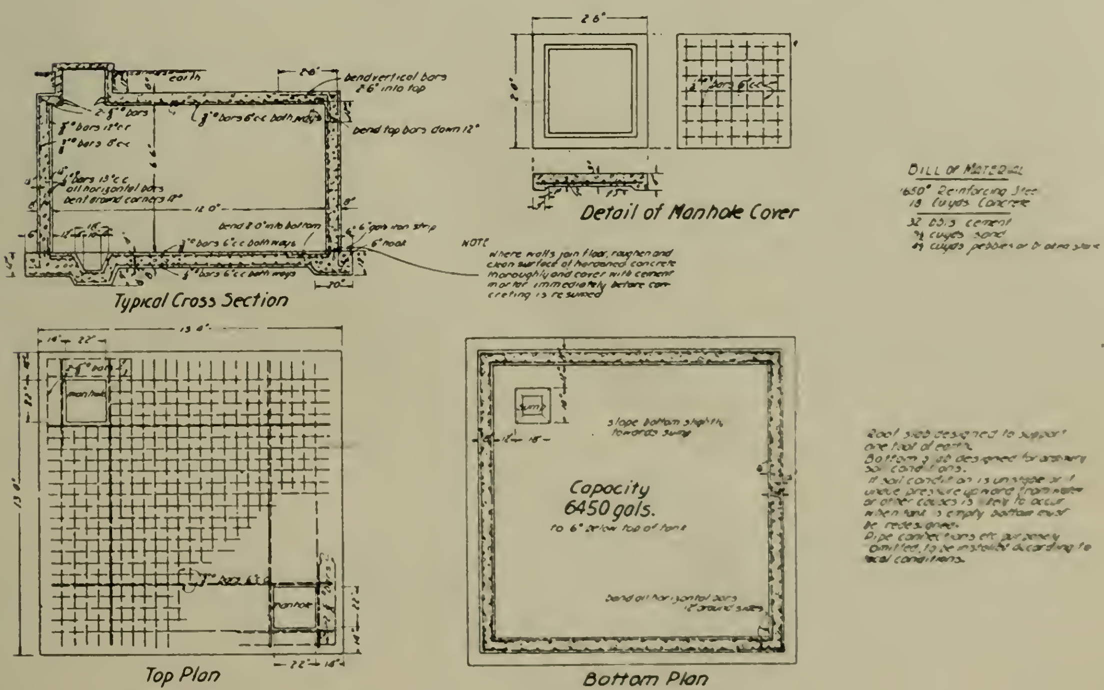
the inside form and engaging both floor and wall, and after wall form is removed the 1-in. recess is to be plastered with a 1 : 1½ mortar to make a 6-in. coved base.

Treatment of Concrete Surface.—As some owners will insist on a guarantee of oil-tightness for a term of years and as contractors who figure work on a contract basis in competition will not usually guarantee work designed by others, it may be found desirable to use an oilproof skin coating regardless of the density of the oil to be stored, applied by a reliable contractor who guarantees his work.

BACKFILLING.—Backfilling should not be done around the walls nor deposited on the roof until, in the opinion of the engineer in charge, it can be safely done.

VENTING OF TANKS.—(*a*) An independent, permanently open galvanized iron vent terminating outside of building shall be provided for every tank.





(*b*) Vent openings should be screened (thirty by thirty nickel mesh or its equivalent) and shall be of sufficient area to permit proper inflow of liquid during the filling operation and in no case less than 2 in. in diameter. Vent pipes shall be provided with weatherproof hoods, and terminate 12 ft. above the top of fill-pipe, or, if tight connection is made in filling line, to a point 1 ft. above the level of the top of the highest reservoir from which the tanks may be filled and never within less than 3 ft. measured horizontally and vertically from any window or other building opening.

Tanks of 500 gals. capacity or less may be provided with a combination fill and vent fitting so arranged that fill-pipe cannot be opened without opening the vent pipe.

(*c*) Where a battery of tanks is installed, a vent pipe may connect to a main header, but individual vent pipes shall be screened between tank and header. The header outlet shall conform to the foregoing requirements.

Filling Pipe.—End of filling pipe in tank shall be turned up so as to form a trap or seal, and when installed in the vicinity of any door or other building opening shall be as remote therefrom as possible so as to prevent liability of flow of oil through building openings: terminal shall be outside of building in a tight, incombustible box or casting, so designed as to make access difficult by unauthorised persons.

Manhole.—Manhole covers shall be securely fastened in order to make access difficult by unauthorised persons. No manhole should be used for filling purposes.

Test Well or Gauging Device.—A test well or gauging device may be installed provided it is so designed as to prevent the escape of oil or vapour within the building at any time. The top of the well should be sealed, and where located outside of a building, kept locked when not in use. Where indicating devices are used, they should be connected to substantial fittings that will minimise the exposure of oil. No device should be used the breakage of which will allow the escape of oil.

Pipe Fittings.—If pipes pass through the walls they should be flanged sections with a space of about 1½ in. left between the flange and the concrete on each side of the wall: this space should be caulked later with litharge and glycerin or other approved oilproof material. It is advisable also to have a ring projecting about 2 in. around the pipe sleeve which engages the concrete.

Care of Surface Water.—(*a*) In many cases it becomes necessary to construct reinforced concrete tanks in localities near tidewater, rivers, streams or water basins where water pressure may be derived through porous soils. Care should be taken to keep this water pressure from fresh concrete until it has attained sufficient strength to fully resist the assumed hydrostatic pressure.

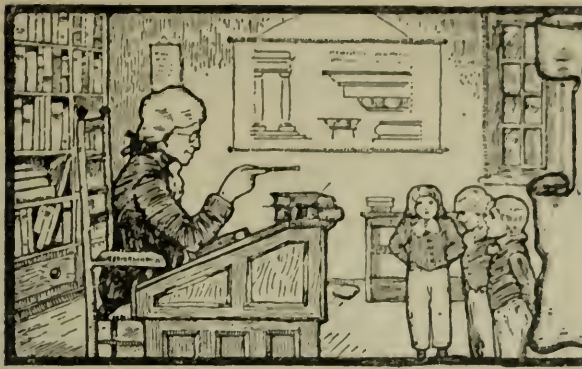
(*b*) One or more sumps should be provided and the floor should be underdrained so that water will flow freely to the sump. Suitable pumping facilities should be provided so that water can be pumped continuously. A flange pipe projecting just above the floor may be built into the concrete and the top of the pipe covered with a cap to be bolted or screwed down when pumping is no longer considered necessary.

(*c*) If it becomes necessary to sheet-pile or shore the tanks, the shores should be so designed that they will not pass through the walls and thus leave openings that it would be necessary to fill later.

Cleaning out Tanks: Warning.—It is dangerous to life to enter fuel-oil tanks soon after they are opened. There is danger of suffocation from oil fumes on account of the absence of sufficient oxygen. Therefore, it should be required that all manhole covers be left off to admit complete diffusion before workmen enter, and to accelerate this diffusion the use of a compressed air line is advised.

MEMORANDUM.

Old Cambridge Men and the Cambridge School of Architecture.—A number of architects who are old Cambridge men have just formed a Club with a view to helping, wherever possible, the work of the Cambridge School of Architecture. As a first step they have agreed to double the donation of £50 given this year by the R.I.B.A. to the funds of the School, and they propose in future to meet once a year, either in Cambridge or London, to establish relations with the Staff of the School and to keep in touch with its work generally. Mr. Maurice E. Webb, F.R.I.B.A., has been elected Chairman of the Club, and Mr. J. Aln Slater, A.R.I.B.A., Hon. Secretary and Treasurer.



SIMPLE EXAMPLES OF REINFORCED CONCRETE DESIGN.

(Continued.)

By OSCAR FABER, O.B.E., D.Sc., etc.

Example.

Warehouse floor 100 *ft.* × 100 *ft. carried on concrete columns. Load* 300 *lb. a foot inclusive. Two stories of* 12 *ft. with a flat roof over.*

The first decision that needs to be made is the centres of columns.

Considerations of economy in this matter generally fix the most economical spacing as, roughly, the distance between floors.

As in the present case, however, this would be so close as to be a serious obstruction, and the best solution must be a compromise between economy and utility, which will need deciding on the merits of each case specially.

In the present case we will settle on 25 ft. spacings in both directions, which gives fine open spaces.

The next decision is the arrangement of beams. Probably a flat slab or mushroom design would need to be considered, but this can hardly be considered a "simple example," and must be left to more experienced hands at present. In any case, it by no means always furnishes the best solution.

Remembering that as a general rule a good design should not give a slab thickness greater than about 6 in., it is clear that the slab cannot span the 25 ft. between columns.

Even with single intermediate beams, the slab would be about 12 ft. 6 in. span and therefore just over 6 in. thick for office loads, and clearly more for the present warehouse loads.

We shall therefore be well advised to have two secondary beams between those on the lines of columns, thus dividing every square panel up into three.

The arrangement is now as indicated on *Fig.* 8.

In this example, we will not complicate the work by introducing staircases, lifts, etc.

We will also assume the flat roof is to be designed for the heavy floor load, so that it could at a later date be used as a floor and have a light roof built on it.

We can now proceed as follows :—

FLOOR SLAB.— Span $= \frac{25}{3}$ ft. $=$ 8 ft. 4 in.

Bending moment : $B = \frac{Wl}{12} = \frac{(300 \times 8\frac{1}{3}) \times 100 \text{ in.}}{12}$

$= 20{,}800$ in., lb. per ft. width.

With stresses of 16,000 and 600 lb. in.² in steel and concrete respectively and ·675 per cent. of steel, we have

Resistance moment : $R = 95\, bd^2$ whence, remembering $b = 12$ in., and $R = B$,

$$d = \sqrt{\frac{20{,}800}{95 \times 12}} = 4\tfrac{1}{4} \text{ in.}$$

Hence a 5 in. slab gives reasonable cover. Area of steel per ft. width of slab

$$A = \frac{\cdot 675}{100} \times 4\tfrac{1}{4} \times 12$$

$$= \cdot 345 \text{ in.}^2$$

$\frac{1}{2}$ in. rods at 7 in. centres gives this area.

The slab bars should be alternately straight along the bottom, and bent up over the support, as explained on p. 23 of *Reinforced Concrete Simply Explained.*

The cross bars may be $\frac{1}{2}$ in. rods 28 in. apart (i.e., four times the spacing of the main bars).

SECONDARY BEAMS.— Span = 25 ft.

Load per beam = 25 ft. × 8 ft. 4 in. × 300 lb./ft.²
= 62,500 lb.

$$\text{Bending moment: } B = \frac{Wl^*}{12} = \frac{62{,}500 \times 300 \text{ in.}}{12}$$
$$= 1{,}562{,}500 \text{ in. lb.}$$

Referring to the table of standard **T** beams given in *R.C.S.E.*, p. 35, it appears that something between a 22 × 8 and a 24 × 10 is required.

We will, therefore, adopt the larger of these which is on the side of safety. This has eight 1-in. rods in two layers.

We notice from *R.C.S.E.*, p. 35, that the compression slab needs to be 7 ft. 9 in. thick and 42·3 in. wide—actually it is 5 in. thick and 100 in. wide, which gives a more ample area.

So far we have only considered moments at midspan. Coming now to the negative moment at the support, this will have about the same value.

$$B = \frac{Wl^*}{12} = 1{,}562{,}500 \text{ in. lb.}$$

Remembering that most of the secondary beams are supported, not by columns, but by main beams, it will clearly be difficult to provide an appreciable haunch at the end.

We notice that $\frac{B}{bd^2}$ gives the figure

$$\frac{1{,}562{,}000}{10 \times 22^2} = 322$$

instead of the usual 95 bd^2 for rectangular beams.

If we have eight 1 in. rods on the tension side (on top at the support) this will clearly be ample, since this was ample for midspan, and both the moment and depth at the end are unchanged.

The compression side would then be greatly overstressed, but we can relieve it by using rods on the compression side (the bottom).

As regards the number and size required, the L.C.C. allow an area equal to that on the tension side. For large percentages, this has little justification, but we will accept it for the purpose of these simple examples.

Coming now to Shear, we will consider the beam divided into panels, with the rods arranged as in *Fig.* 9.

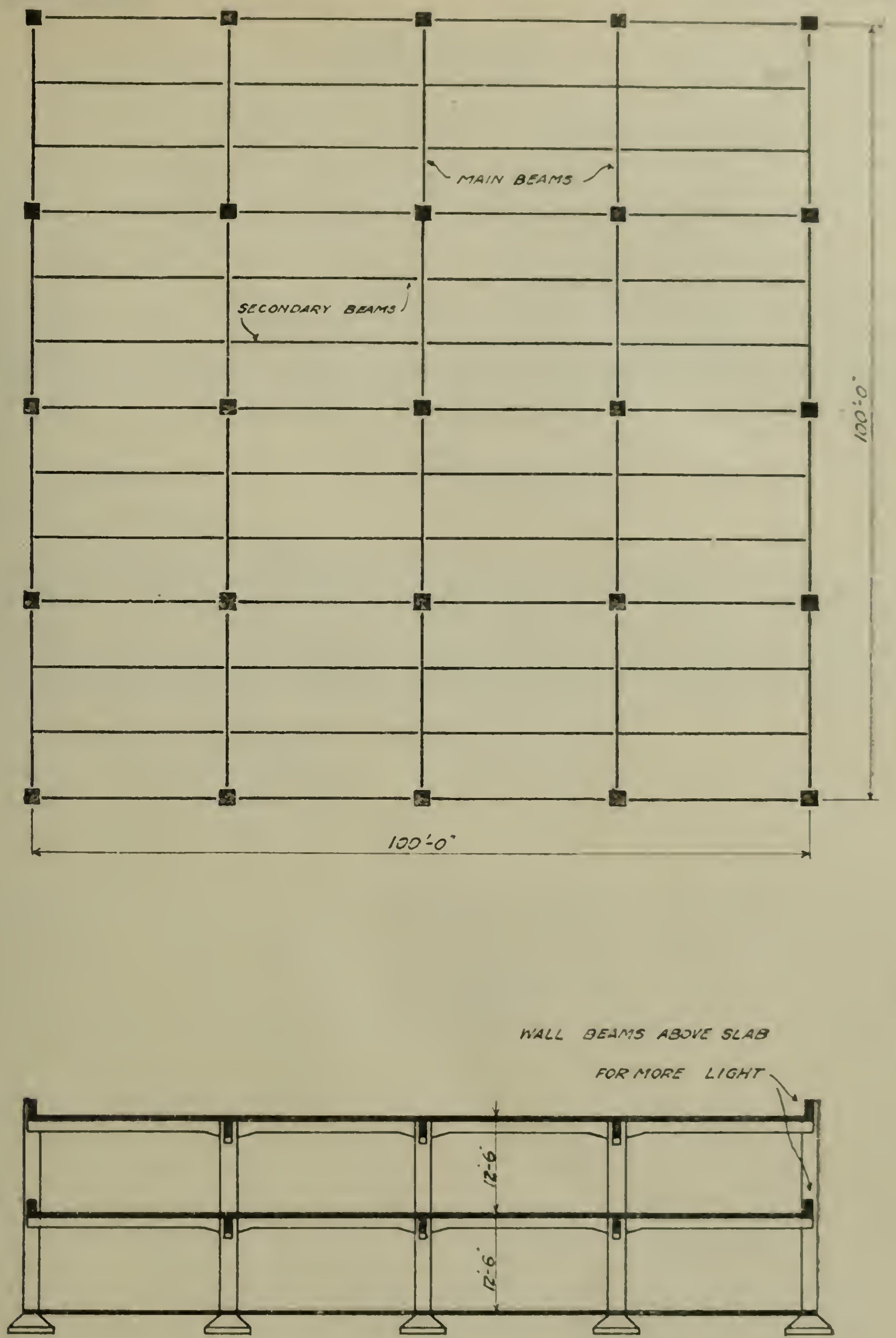
PANEL 1.—*Shear* = $12\frac{1}{2} \times (8\frac{1}{3} \times 300) = 31{,}250$ lb.

Shear Resistance due to			lb.
Inclined tension members (two 1 in. rods)	$1 \cdot 56 \times 10{,}000 \times \frac{20}{30}$	=	10,400
Inclined compression		=	10,400
Stirrups ($\frac{1}{2}$ in. loops at 8 in. centres) .	$\cdot 4 \times 10{,}000 \times \frac{20}{8}$	=	10,000
			30,800 lb.

This agrees well enough with the actual Shear.

PANEL 2.—*Shear* = $31{,}250 \times \frac{10\frac{1}{2}}{12\frac{1}{2}} = 26{,}500$ lb.

Shear Resistance due to			lb.
Inclined tension	$1 \cdot 56 \times 10{,}000 \times \frac{20}{36}$	=	8,600
Inclined compression			8,600
Stirrups			10,000
			27,200 lb.



GENERAL PLAN AND SECTION

OF FLOORS.

Fig. 8.

PANEL 3.—*Shear* $= 31{,}250 \times \frac{8}{12\frac{1}{2}} = 20{,}000$ lb.

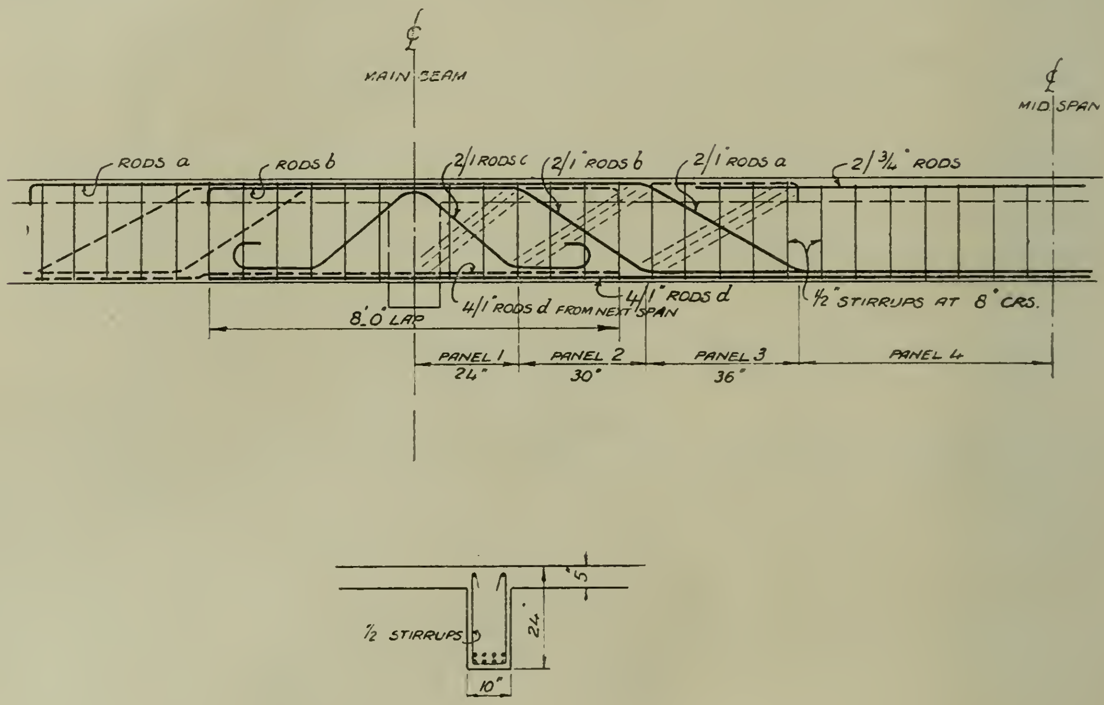
Shear Resistance due to

		lb.
Inclined tension	$1{\cdot}56 \times 10{,}000 \times \frac{20}{42} =$	7,400
Inclined compression		7,400
Stirrups		10,000
		24,800 lb.

PANEL 4.—*Shear* $= 31{,}250 \times \frac{5}{12\frac{1}{2}} = 12{,}500$ lb.

Inclined tension in concrete	20 in. × 10 in. × 60 =	12,000 lb.
Resistance of Stirrups		10,000 ,,

Hence either of these practically meets the requirements alone. They must not be added.



DETAILS OF REINFORCEMENT OF SECONDARY BEAM

FIG. 9

The treatment of Shear as given above follows exactly that explained fully in *Reinforced Concrete Simply Explained.*

The stress in stirrups and shear members has been confined to 10,000, because it is impossible to develop high stresses in the neighbourhood of ends of rods or of bends without producing excessive stresses in the concrete.

Note carefully the lap of 4 ft. on either side of the centre line given to the bars on the compression side. This is necessary if they are to be capable of resisting the 16,000 lb./in.² to which the stress in them may approximate.

The same applies also to the bent bars carried beyond the support, except that here some of the bars are carried a little further to satisfy the requirements of the negative moments.

(*To be continued.*)

* In these articles, only approximate values are used. For accurate values, see *Reinforced Concrete Design*, Vol. II.

RECENT BRITISH PATENTS RELATING TO CONCRETE.

We propose to present at intervals particulars of British Patents issued in connection with concrete and reinforced concrete, the articles being prepared by Messrs. Andrews and Beaumont, Patent Agents, of 204–6 Bank Chambers, 29 Southampton Buildings, W.C.2. The last article appeared in our issue of April 1921.—ED.

Shuttering.—*No.* 160, 867. *L. P. Evans, The Grove, Swanwick, Alfreton. Dated July* 9/20.—According to this invention each section of the shuttering has secured thereto plates with reduced or round projecting ends upstanding from the upper edge of the shuttering and adapted for attachment of connecting wires or perforated metal strips between two companion rows of shuttering, the wires or metal strips lying between

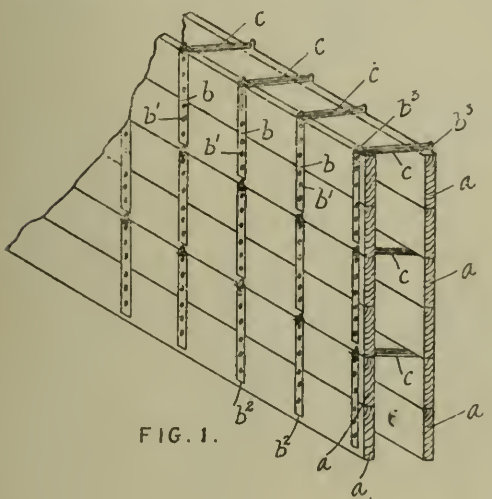


FIG. 1.

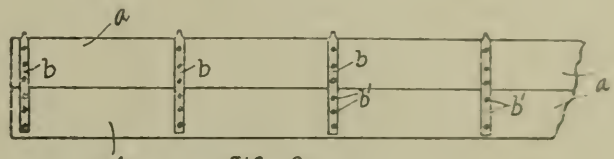


FIG 2.

upper and lower shuttering. The shutters *a* are adapted to be placed one above the other edgewise, so that the projecting end b^3 of each plate *b* overlaps the adjacent board. The two rows of shutters *a* are connected to each other by wires *c*, which are twisted or wrapped round the projecting ends b^3 of the metal plates *b*. In this way the top edges of a pair of shutters are held in position by the wires *c*, and the lower edges by the projecting ends b^3 of the metal plates *b* on the shutters below. After the concrete has set sufficiently, the lowest shutters on each side are released by cutting or untwisting the connecting wires *c*.

Pre-cast Concrete Floor Units.—No. 160, 928. *V. Craig, F.R.I.B.A., M.R.I.A.I., High Close, Wokingham, Berks. Dated December* 30/19.—The invention consists in forming the joist member of a concrete unit of the ⅂ type with means adapted to support ceiling members or elements whereby the ceiling may be hung. The under face or soffit of the flooring may be formed curved or arched so as to strengthen the unit.

The surfaces 3 and 4 are preferably given a curved surface for ease of tamping and they may be formed with a groove 5 and 6 to form a key for grouting material. The lower portion of the web part 1 of each of the units is preferably enlarged as at 7 or moulded as at 7^a, or in any other desired shape. These enlarged portions are adapted to serve as a support for wooden ceiling supporting pieces 8, the ends of which are notched to correspond with the angular or moulded faces upon the web portions of the units. These ceiling supporting pieces 8 are jammed or hung in position by turning them transversely between the webs 1 of the units.

A suitable mould for the units according to the invention may be constructed as follows :—A box is provided which in shape in cross section is that of an L, and is formed with horizontal and vertical beds 13 and 14 of a shape corresponding to the under or inner sides of the unit. The outer side 15 of the box is hinged to the lower or base portion 16, and the inner surface of this hinged side is made with a ledge 17 to form the mould for the seating upon which the flooring elements are supported. The part 17 may be made integral with the side 15 of the mould or it may be hinged thereto to facilitate ramming and filling operations. The opposite side of the horizontal bed 13 is provided with a moulding surface 18 for forming the faces 4 of the units. This moulding surface is preferably formed upon a board 19 of the same depth as vertical bed 14, so that the two parts together constitute a stable support for the mould. Stiffening pieces 19ª may be introduced between the board 19 and the part 14 at suitable intervals apart.

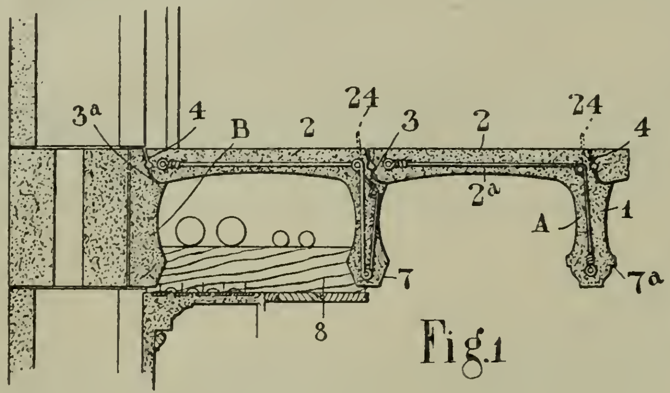


Fig.1

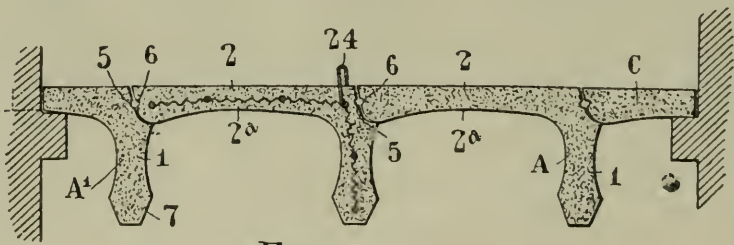


Fig.3

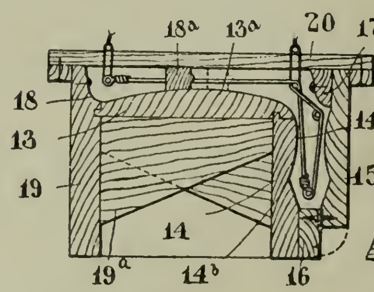


Fig.6.

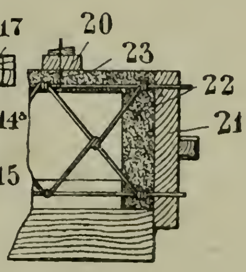


Fig.7.

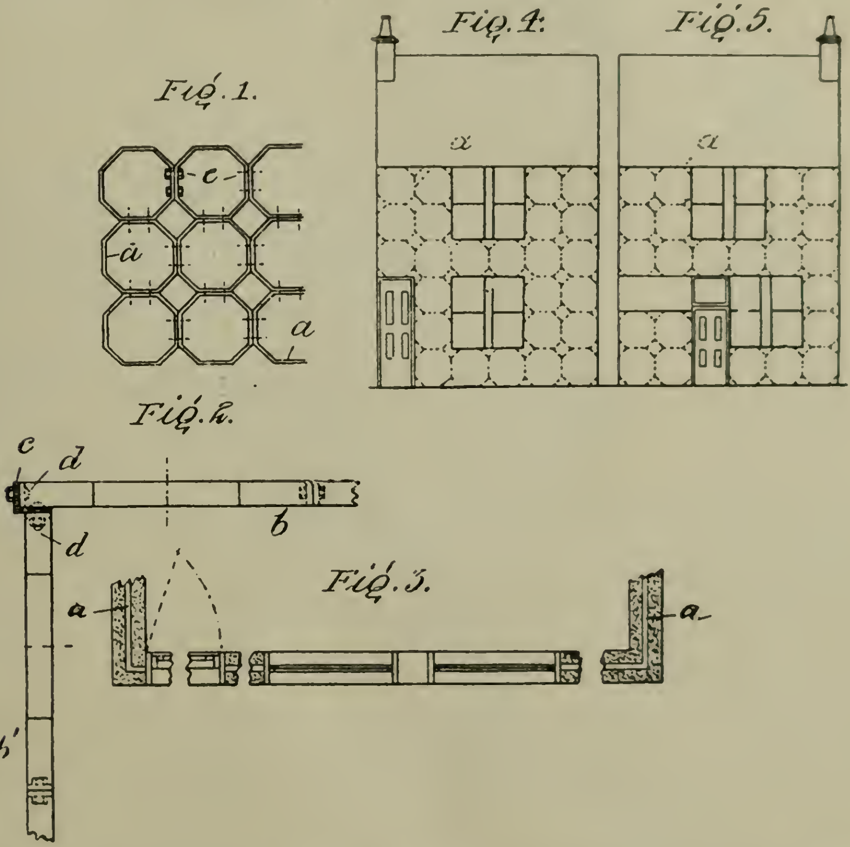
In order that the ends of the units *A* may be cast solid if so desired, the ends 21 of the mould may be situated so as to leave a space 22 beyond the ends of the beds 13 and 14.

The ends of the box or mould may be adapted by the provision of suitable holes to support longitudinal reinforcing elements which may be afforded auxiliary support by wires 23 secured to the cramping means 20.

It is preferred to provide wire loops 24 extending from the heel reinforcing bar outwardly. These loops stand out from the concrete for the purpose of providing convenient means for hoisting the units into position. These loops may be removed when the floor is finished.

Reinforcement for Concrete Buildings.—*No.* 161, 002. *J. T. Simpson, South View, Thornley, Durham. Dated January* 24/20.—The basis of the present invention is a reinforcing skeleton of lattice-like formation as distinguished from a skeleton block or brick. This reinforcing skeleton is built up of conjoined preferably like or similar cell-like sections.

In the construction *in situ* of a house or like building or structure, the erection of the whole of the built up skeleton of cell-like sections preferably octagonal, including the roof, may be completed, and all doors, windows, joists, floorings, and fittings put in before filling in with concrete or the like. The lowest set of rings is suitably secured to an appropriate foundation, *e.g.*, such lowest set may be bolted to a suitable base plate and bedded in a concrete or like foundation. Inside the outside shuttering is arranged in accordance with the desired thickness of the wall, and this shuttering and the cell-like sections are then filled with the concrete of like material.

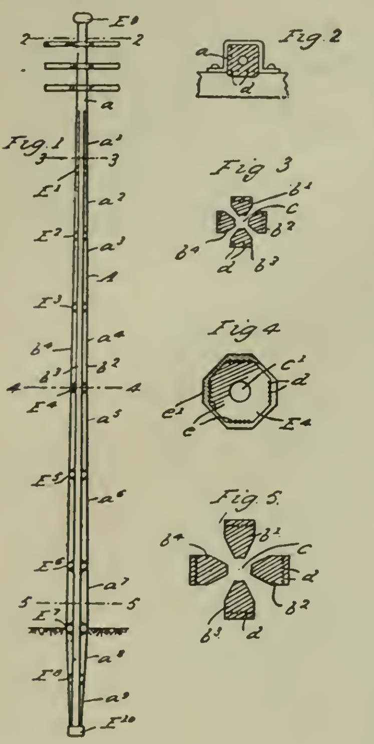


Referring to the drawings, *a* designates a conveniently octagonal, cell-like section, adapted as shown for conjoining with other like or similar sections in cellular formation, or a formation of that character, by which a skeleton of built-up rows of such conjoined sections is readily made available for reinforcing concrete or the like in general, and for reinforcing the walls of buildings or structures or the like in particular as indicated in *Figs.* 4, 5 and 6.

At the corners of the skeleton shell of a house, meeting skeletons as b, b^1 (*Fig.* 2), are appropriately joined or tied together, for example, by means of angle irons *c* and screw-nutted bolts *d*. Screw-nutted bolts *e* may also be conveniently employed for connecting the sections *a* when building the reinforcing skeleton.

The ground plan (*Fig.* 3) shows the position of the skeleton reinforcement in the concrete walls of the building or the like, and also in conjunction with the elevations *Figs.* 4 and 5, and 6 shows how any fitting, such as a casement, door, or the like may be accommodated by removing or omitting one or more of the cell-like sections when the relative proportions of the sections and fittings are brought into conformity for that purpose.

Reinforced Concrete Posts.—*No.* 161, 071. *F. W. Bradshaw,* 121 *Coogee Street, Mount Hawthorn, Perth, W. Australia. Accepted April* 12/20.—The reinforcing members of posts are secured by binding wires to previously moulded transverse diaphragms arranged at intervals along the length of the column or post and are covered during the moulding process by a layer of concrete.



The diaphragms are provided with a central aperture corresponding to the central space around which the vertical members are grouped, so that when the columns are used as telegraph or like posts conductors can be led through the axial aperture.

In the example illustrated, *A* is a reinforced telegraph pole comprising an upper terminal section *a* and lower sections a^1-a^9, of which the sections a^8 and a^9 are buried in the ground; each section is composed of four vertical members b^1-b^4, of the shape shown, symmetrically arranged round the central axial aperture *c*. Reinforcing members *d* are formed in the heavier constructions of iron or steel rods and in the lighter constructions of large gauge wire.

The sections rest on transverse diaphragms E^1-E^8, which also form caps for the sections immediately below them. The diaphragms are shown as octagonal in outline, though this form may be varied, and are provided with a central aperture c^1 corresponding to the central space *c* in the longitudinal members.

The upper and lower faces are inclined at an angle of about 45° to the horizontal to prevent moisture from lodging on the surfaces.

The reinforcing members are embedded to a depth of about half their diameter in V-shaped recesses *e* provided in the external periphery of the sides of the diaphragms, and in the moulding operation a layer of concrete e^1 of not less than half an inch is added to the external dimensions of the diaphragms to protect the reinforcing members.

Loops or hooks are formed at the end of each reinforcing rod, for binding and straining purposes wires are wound round the hooks to bind all the rods together, and the loops are finally embedded within terminal caps E^9, E^{10}. A mould for use in casting the poles is described.

Block Structures.—*No.* 166, 753. *J. F. Hunt,* 14 *Smalley Road, Stoke Newington, London, N.*16, and *L. V. Caesar,* 20, *Coolhurst Road, Crouch End, London, N.*8. *Dated May* 4/20.—This invention relates to the building of hollow or cavity walls wherein the inside and outside walls are built of concrete slabs or blocks formed with stiffening projections upon their opposed surfaces arranged transversely of the slab or block, which projections, when said walls are built, are in vertical alignment and face one another—but do not meet—and are spaced apart by metallic ties in such manner that a continuous channel is formed between the walls.

In the building of cavity walls of this kind, it has been proposed to form a cavity block of two slabs connected and spaced apart to form a continuous channel between the walls by metal ties and which slabs have their inner faces inclined in two directions from given points and forming four faces of equal length, so that as the blocks are built and bonded one on another the edges will coincide.

And again it has been proposed to provide each slab in the middle of its inner face with a wing or rib at the top of which is formed a notch to take one of the tenons of a key serving as a bond between the two walls, the ribs or wings of one wall being opposite those of the other, but do not meet, the space between forming a continuous cavity between the walls, while in such arrangement provision is made for constituting the corners or angles and the jambs or abutments of the wall by a prolongation of the slab in the shape of a dovetail which enables it to be anchored in the concrete.

The present invention consists in the use in a system of building cavity walls of standard blocks, consisting of a maximum of four sections which may be all integrally united, or wholly or in part separated in the mould, each section being provided with a stiffener transversely to the block and centrally of the several sections, so that all blocks are multiples of the elemental or quarter-unit block.

The blocks *A* are rectangular slabs with vertical projecting stiffeners *D* at back and are either grooved and tongued at the vertical meeting edges or butted as shown.

The standard or unit block has four stiffeners (*Fig.* 13), the $\frac{3}{4}$ unit block has three stiffeners (*Fig.* 12), the $\frac{1}{2}$ unit block has two stiffeners (*Fig.* 11), and the $\frac{1}{4}$ unit block has one stiffener (*Fig.* 10). These standard blocks are made divisible by arrangement in the machine or by metal strips in the hand moulds in a manner well-understood in the art.

The same blocks are used for the inside and outside walls of a cavity wall except that the blocks of the inside wall are usually cast of breeze or other suitable aggregate, and the blocks of the outside wall are usually cast of ballast or other suitable aggregate.

The blocks are built to bond together in the ordinary way, and ordinary iron or twisted wire wall ties are used at convenient intervals.

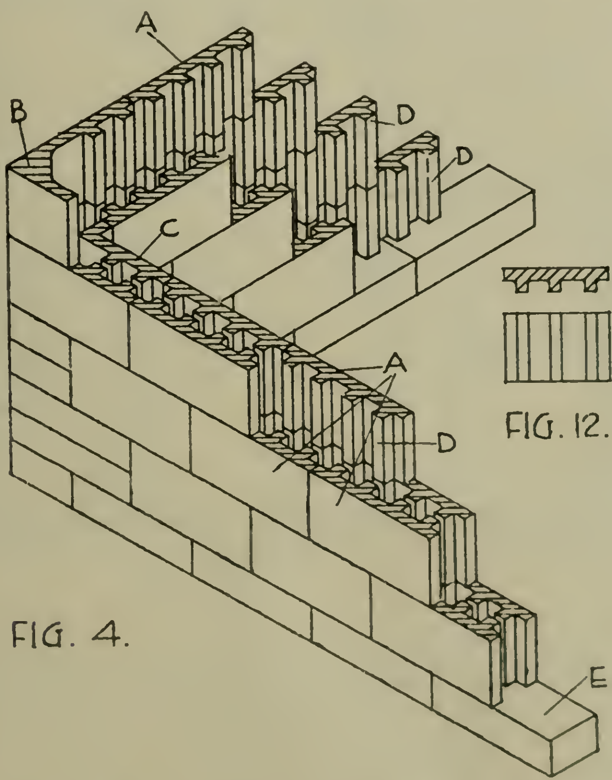


FIG. 4.

FIG. 12.

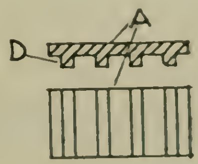


FIG 13

Should a pier be required in a given length of walling it can be formed by filling up the cavity between two or more stiffeners as the work proceeds.

Where angle blocks are necessary they are of the shape as shown at *B*, *C* (*Figs.* 2, 3, 4). These are heavier than the previously described blocks as they have a return face, but they may be so divided that two angle blocks equal the height of one ordinary block, thus being half the weight of the full-size angle blocks.

Reinforced Concrete Houses.—*No.* 161, 614. *J. F. Matthews*, 29 *Heathfield Avenue, Dover. Dated November* 15/19.—The base member *b* of a house is formed of reinforced concrete and has apertures therein at suitable intervals to receive the wall studs *f* and floor joists *g*, the latter being separately formed of reinforced concrete in any suitable manner and being of a size and shape to correspond with the size and shape of the apertures provided for their reception in the base member *b*, the reinforcements of the studs and joists being left projecting beyond the ends of same so that they may be suitably hooked to or otherwise connected with the reinforcement of the base member in any known manner, the junctions of such respective members being afterwards grouted to complete the joints.

Round the outer edge of the flooring slabs is formed a shallow rebate or depression in order to take the reinforced concrete skirtings *i* which serve as bearings for the inner wall slabs *e*, the wall slabs or such of them as may be necessary being moulded with holes or apertures for the reception of bolts *k* connecting the slabs or connecting the outer slabs and skirtings or cornices.

The reinforced cornices *l* are moulded to form one piece with the ceilings *m* and picture rails *n*, and the reinforcements of the studs are connected with the reinforcement of the cornices in any known manner, the upper floors *h* being provided with apertures to enable the reinforcements of the upper studs to pass there through to the cornices.

Reinforced concrete roof trusses comprise rafters *v*, central upright v^1, diagonals v^2 and horizontal tie beam v^3, the rafters overhanging the walls to form eaves and being suitably hooked or otherwise formed at the extremities v^4 to carry gutters.

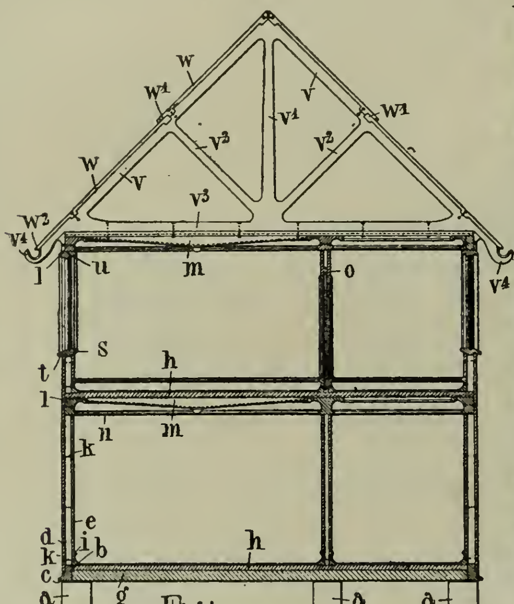


Fig.1

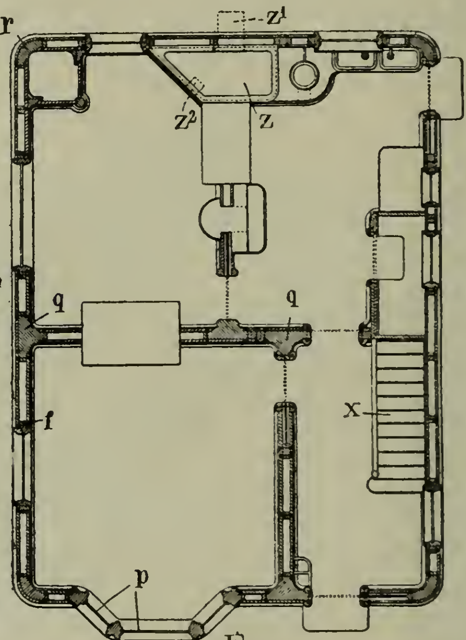


Fig.2

Notches are formed in the upper side of the rafters to serve as stops for the roof slabs *w* which are preferably of such dimensions that the ends meet over dividing walls, and so that the high roof section will overlap the lower section with the centre of the lap w^1 immediately over the diagonal struts v^2 of the roof truss.

Concrete Mixers.—*No.* 166,002. *J. B. Harvey,* 10 *Stretton Road, Croydon. Dated May* 3/20.—This invention relates to concrete mixers of the worm type having cylindrical casing mounted on a horizontal or inclined axis and is characterised in that the axle passes through the cylindrical casing and has disposed on it one or more helical blades, of a width such that the inner edge or edges are in contact with the axle and the outer edge or edges in contact with the cylindrical casing.

A framework *a* has bearings *b* on the framework in which is mounted an axle *c*, *d* being a cylindrical casing mounted on the axle *c* having a tapered portion *e* at its open end and an end plate *f* at its closed end. A helical blade *g* is provided within the casing, and a hopper *h* leads into the open end of the cylindrical casing *d* ; a discharge door *i* is provided in the end plate *f*, and a sleeve *j* is loosely mounted on the axle *c* and is operated by a lever *k*.

The axle *c* may be made hollow and provided with holes or perforations *r* to admit water to the concrete in the casing, and the end *s* of the axle *c* may be provided with a packing gland adapted to receive the end of a water main.

In use a charge to be mixed is fed into the hopper *h* and the shaft *n* and casing *d* are rotated. The rotation of the casing *d* and helical blade *g* causes the charge to be mixed to travel towards the closed end of the casing *d*. When the charge arrives at the end of the casing *d* the end plate *f* causes it to fall over the end of the helical blade *g* and down a small distance in the casing *d* towards the open end. The rotation of the casing *d* brings the charge up to the end plate *f* once more and the process is repeated. When the contents of the casing *d* have been sufficiently mixed the discharge door *i* is opened by means of the lever *k* and the charge is forced out into any suitable receptacle by the rotating blade *g*.

Fig. 1.

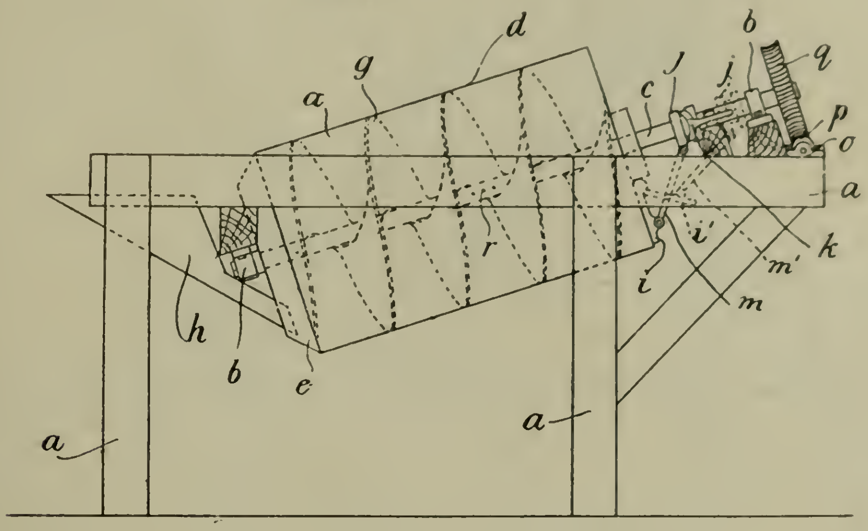
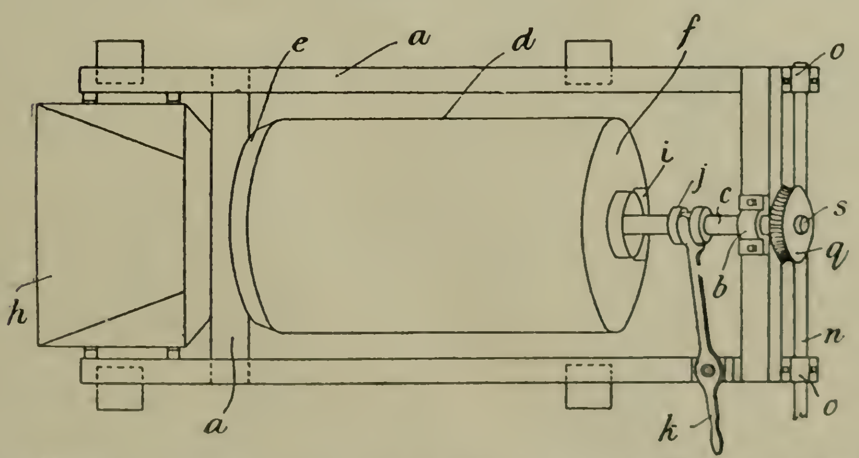


Fig. 2.



Concrete Mixers.—*No.* 166, 421. *G. A. Tonkin*, 43 *Elgin Crescent, North Kensington London, W.*11. *Dated May* 28/20.—This invention relates to concrete mixers of the kind known as batch mixers, comprising a mixing vessel mounted to tilt about trunnions extending from its ends near its upper edges adjacent to one side, this arrangement permitting the vessel to be kept low down near the ground whilst providing ample room for accommodating a barrow or the like below the discharging edge of the mixing vessel when tilted.

According to this invention, the mixing vessel is turned on the trunnions to raise it, by means of a chain or rope attached to the vessel below the upper edges and passed over the upper edge of the side remote from the trunnions to a pulley mounted at a suitable height above the vessel.

The mixing vessel is provided with trunnions *b*, *b* respectively arranged near to the upper edges of the vessel at opposite ends thereof and adjacent to one side, and these trunnions are rotatably mounted in bearings provided in a frame *e*, and is supported in a position to allow materials to be placed therein by the bottom of this vessel coming to rest on a frame part *d* as shown in *Figs.* 2 and 3. For conveniently tilting the vessel *a* in order to empty it, a winch *e* with a handle *f* is provided at one end of the frame. A chain or rope *g* extends from this winch over a pulley *h* mounted at a suitable height on a post *i* secured to the frame *c*, and this chain or rope is attached to

Fig. 1.

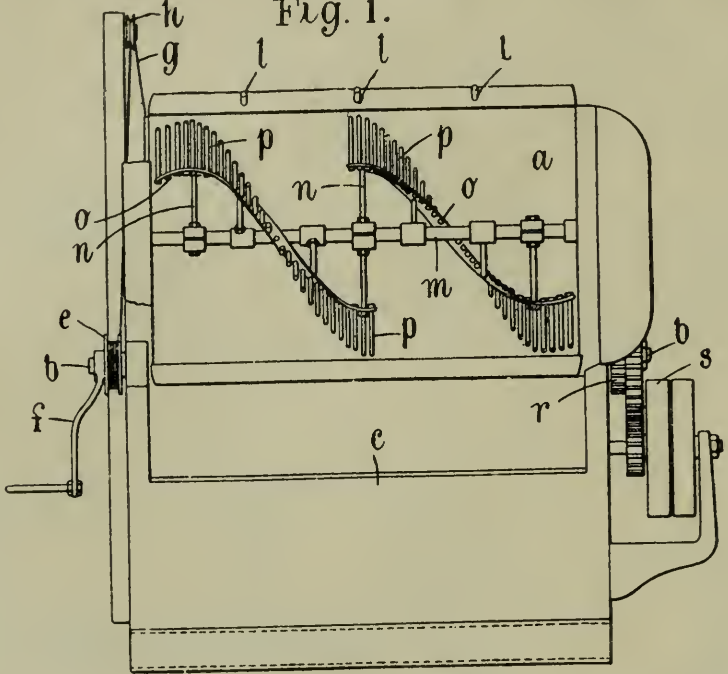


Fig. 2.

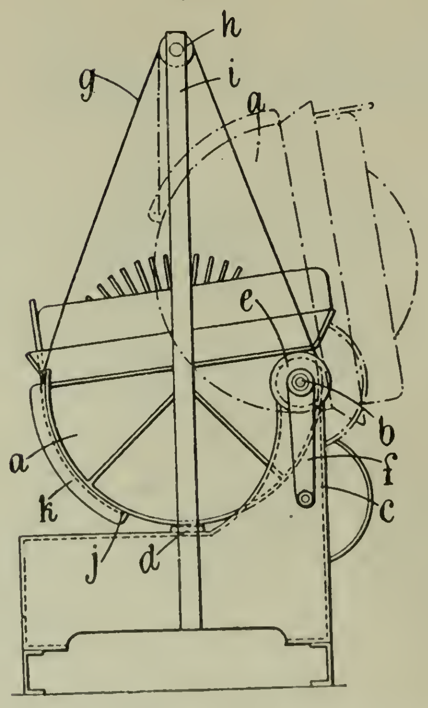
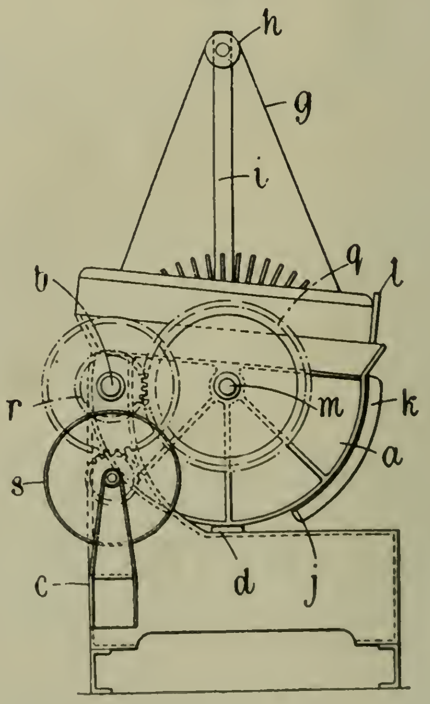


Fig. 3



the vessel *a* preferably at a position such as *j*. A guard plate *k* is provided to guide the chain or rope round the outside of the vessel *a* and to prevent it from slipping over the edge of the vessel. By winding up the chain or rope *g* on the winch *e*, the vessel *a* can be tilted from the position in which it is shown in full lines in *Figs.* 2 and 3 into the position in which it is shown in *Fig.* 1 and in broken lines in *Fig.* 2.

A rotary device for agitating and mixing the materials introduced into the vessel *a* comprises a shaft *m* carrying radial arms *n* to the ends of which helical bars *o* are attached. A number of prongs *p* are arranged on these bars after the manner of the teeth of a rake and the bars have an opposite twist, so that when the shaft *m* is rotated the prongs *p* have a tendency to drive the material from the ends of the vessel *a* towards the middle.

Reinforced Concrete Pipes.—*No.* 166, 630. *B. Bradley,* 2 *Carlton Bank, Harpenden, Herts. Dated March* 16/20.—This invention consists broadly in a curved pipe or bend comprising suitable reinforcements for the walls thereof embedded in concrete consolidated by centrifugal action.

The curved moulds are conveniently formed as segments of circles adapted to be connected together to form a closed ring, and means are associated with the segments whereby the core elements may be secured in the desired position in the mould to perform their function as cores.

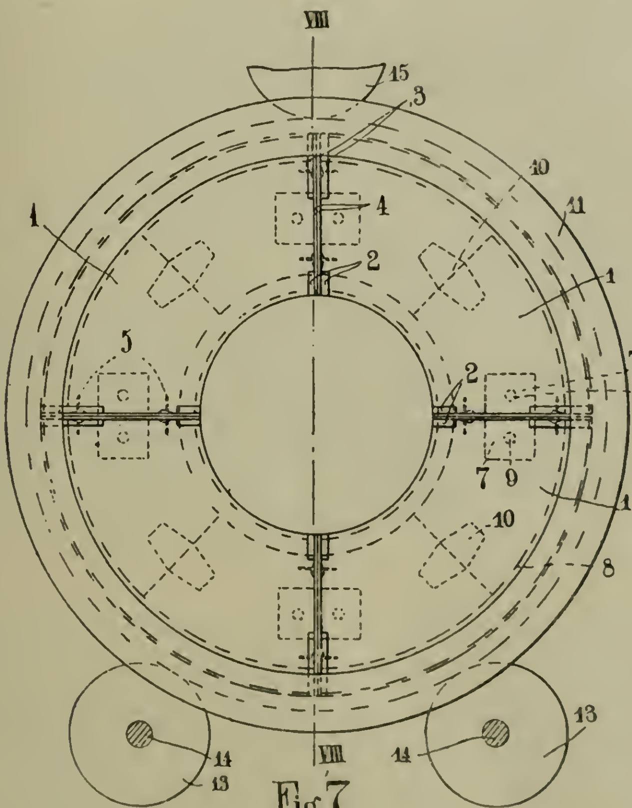


Fig. 7.

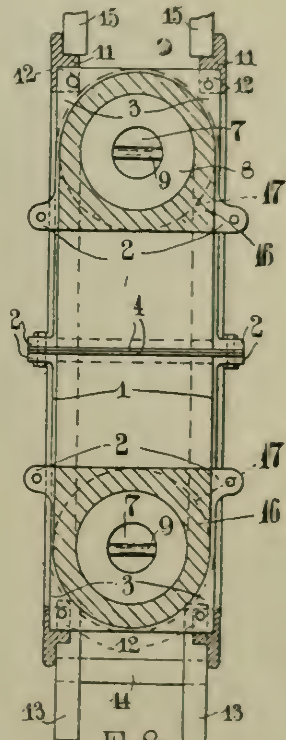


Fig. 8.

Figs. 7 and 8 illustrate a set of mould segments secured one to the other and forming a closed ring in position to be rotated, 11 are flanged rolling rings provided with lugs 12, whereby when in position they may be secured to the mould segments by means of bolts passing through holes in the lugs and in the outer lugs 3 on the mould segments ; 13 are rollers mounted on shafts 14, which are rotated in order to effect the rotation of the set of mould segments, while 15 are rollers adapted to be brought into the position shown to act as a safety device in preventing the set of mould segments falling over sideways during rotation, and 16 in *Fig.* 8 represents the body of the pipe within the mould, the excess of concrete at the ends of the said body being pared off along the line 17, when the pipe has been removed from the mould to give it a circular cross section at these points for the purpose indicated above.

Reinforced Concrete Houses.—*No.* 161, 258. *C. M. J. Roch and L. G. Mouchel & Partners, Limited, both of* 38 *Victoria Street, London, S.W.*1. *Dated January* 2/20.—This invention relates to the construction of reinforced concrete houses of the type in which pre-cast members are provided with channels or grooves in which are disposed reinforcing rods or wires, the channels or grooves being adapted to be filled with concrete when in position.

Reinforced concrete houses of this type made in accordance with this invention are characterised in that embedded in the pre-cast concrete columns or beams are free ended wires in pairs twisted together over the reinforcing rods or wires for tying in such reinforcing rods or wires.

The corner columns *a* are reinforced in any suitable manner, and embedded in the concrete are wires *m* with loops and ends to tie in the horizontal reinforcing wire *t*. The corner of the column is chamfered and forms a pocket to receive concrete during erection.

The intermediate columns *b* are provided with grooves *n*, and embedded in the concrete are wires *m* for tying in the horizontal reinforcing wires.

Fig 3

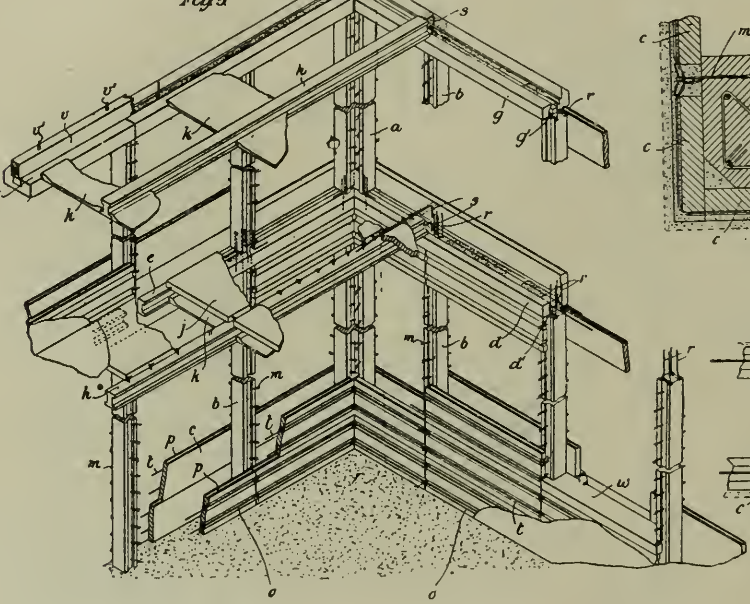


Fig 1

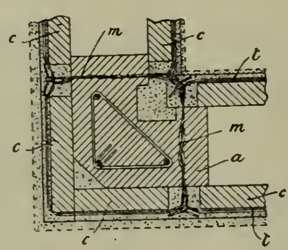
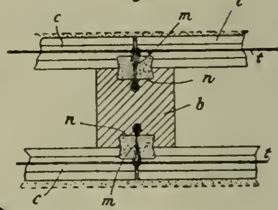


Fig 2



The floor slabs, ceiling slabs and wall slabs may be reinforced in any suitable manner.

To erect a building in accordance with this invention, the corner columns *a* are placed on a foundation of concrete ; the intermediate columns *b* are then erected on a bed of concrete and the ends embedded in concrete. The lintels *d* and beams *e* are then placed in position. The secondary beams *h* are then placed with their ends on the lintels. The ceiling slabs *k* and floor slabs *j* are then placed in position and the lintels reinforced with longitudinal reinforcing members and concrete placed in the trough of the lintel ; the beams *h* are provided with projecting ties *s*.

While this part of the work is in progress the wall slabs are placed in position inside and outside the columns, jointed with cement mortar, and held to the columns by longitudinal wires *t* which are tied by the looping wires *m*. The external and internal faces of the wall slabs are rendered with plaster.

CRIBS AND GRANARIES.

The first part of this article appeared in our September (1921) number on page 604 and dealt mainly with the planning and construction of cribs and granaries.

Pressure of Small Grain.

Several formulas have been developed for calculating the pressure in grain bins: (1) Janssen's Solution and (2) Airy's Solution. The results of these two methods agree very closely with experiments.

Since these formulas are lengthy and involve considerable calculation, they will be illustrated by graphs. The graphs of the two formula—Janssen's and Airy's—

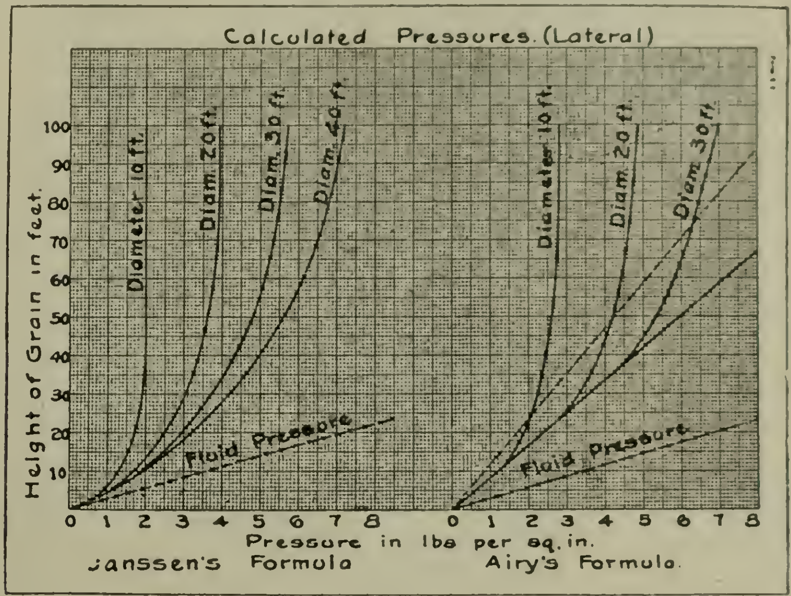


Fig. 11.

are shown in *Fig.* 11, for lateral pressure for wheat. These agree closely in shape, the Janssen's formula pressures being less than those from Airy's calculations.

Some experiments have been conducted to verify these calculations. One, conducted by J. A. Jamieson in 1900, on a full size bin of the Canadian Pacific Railway elevator, West St. John, N.B., is shown in graph on left in *Fig.* 12. The bin was of timber crib construction, 12 ft. × 13 ft. 6 in. in size, and 67 ft. 6 in. high. Manitoba wheat, weighing 49·4 lb. per cu. ft. was used. The calculated pressures from Janssen's formulas are shown on right in same figure. It is to be noted that the curves are identical in shape and are close in value.

The results of another test made on a bin while filling, by Prof. Henry T. Bovey, McGill University, Montreal, in 1901, are shown by graphs in *Fig.* 13. This bin was of wood construction, 12 ft. × 14 ft. in size. The height above centres of diaphragms on which pressures were determined was 44 ft. 10 in.

A set of graphs showing the percentage of wheat carried by bin wall and floor is shown in *Fig* 14. These graphs are the result of Jamieson's tests on a model wooden bin 12 ft. × 12 ft. by 6 ft. 6 in., for wheat weighing 50 lb. per cu. ft.

Jamieson in further tests found that corn weighing 56 lb. per cu. ft. will give approximately the same pressure as wheat. Peas weighing 50 lb. per cu. ft. will give approximately 20 per cent. greater pressure than wheat, while flaxseed weighing 41·5 lb. per cu. ft. will give 10 per cent. to 12 per cent. greater pressure than wheat.

Since a cubic foot of wheat is heavier than the other grains, except peas, a bin designed for wheat will safely carry all loads for shelled corn and oats, which are lighter

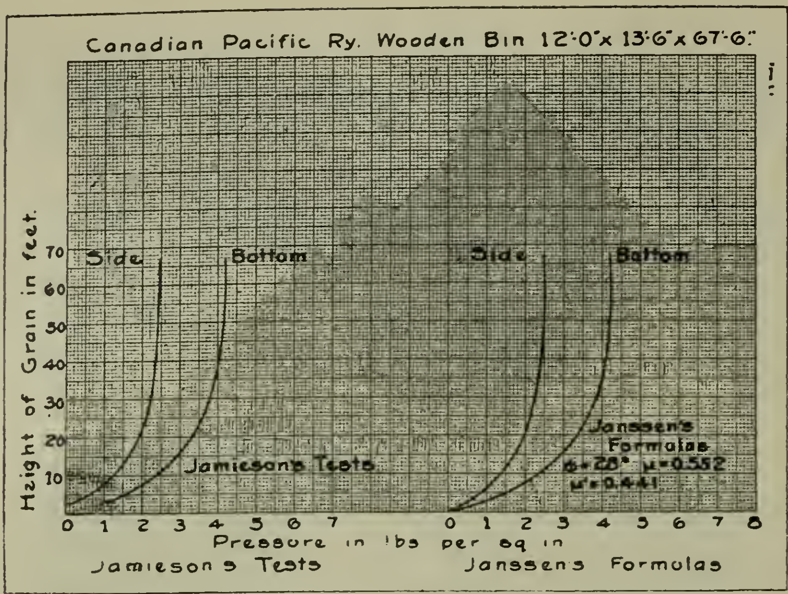


FIG. 12.

In designing bins for peas or beans, add 20 per cent. for strength of bin walls, and for flaxseed add 12 per cent.

The weights of a cubic foot of loosely filled grains in measures are as follows:

Wheat	49 pounds	Beans	46 pounds
Barley	39 ,,	Peas	50 ,,
Oats	28 ,,	Flaxseed	41 ,,
Corn	44 ,,	Tares	49 ,,

It is believed that all farm elevators which are designed with grain bins for the light weight grains should have a safety line prominently painted on inside of bin

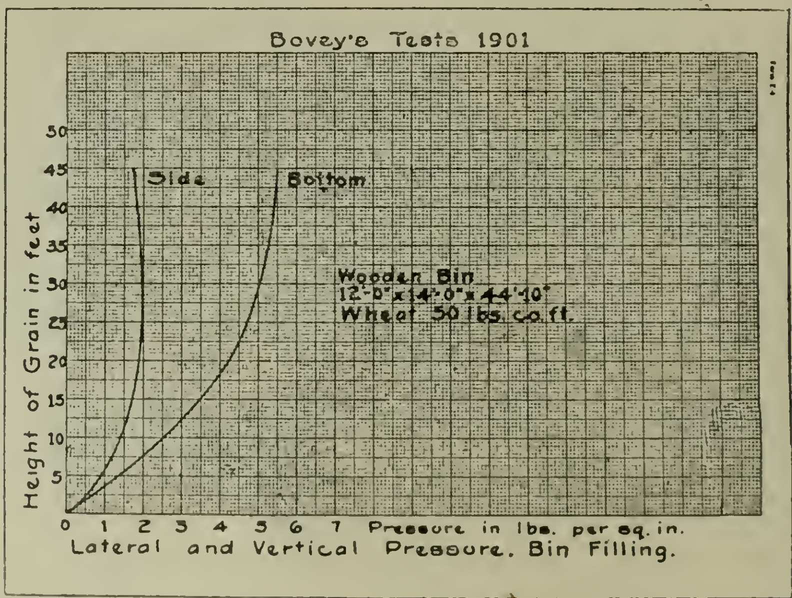


FIG. 13.

and continuous around wall for either wheat or shelled corn. A careful observance of this would prevent a large number of bin failures.

The following conclusions were drawn from the experiments mentioned in this section and others:

1. The pressure of grain on bin walls and bottoms follows a law (which for con-

venience will be called the law of "semi-fluids") which is entirely different from the law of the pressure of fluids.

2. The lateral pressure of grain on bin walls is less than the vertical pressure (0·3 to 0·6 of the vertical pressure, depending on the grain, etc.), and increases very little after a depth of 2½ to 3 times the width or diameter of the bin is reached.

3. The ratio of lateral to vertical pressures, k, is not a constant, but varies with different grains and bins.

The value of k can only be determined by experiment.

4. The pressure of moving grain is very slightly greater than the pressure of grain at rest (maximum variation for ordinary conditions is probably 10 per cent.).

5. Discharge gates in bins should be located at or near the centre of the bin.

6. If the discharge gates are located in the sides of the bins, the lateral pressure due to moving grain is decreased near the discharge gate, and is materially increased on the side opposite the gate (for common conditions this increased pressure may be two or four times the lateral pressure of grain at rest).

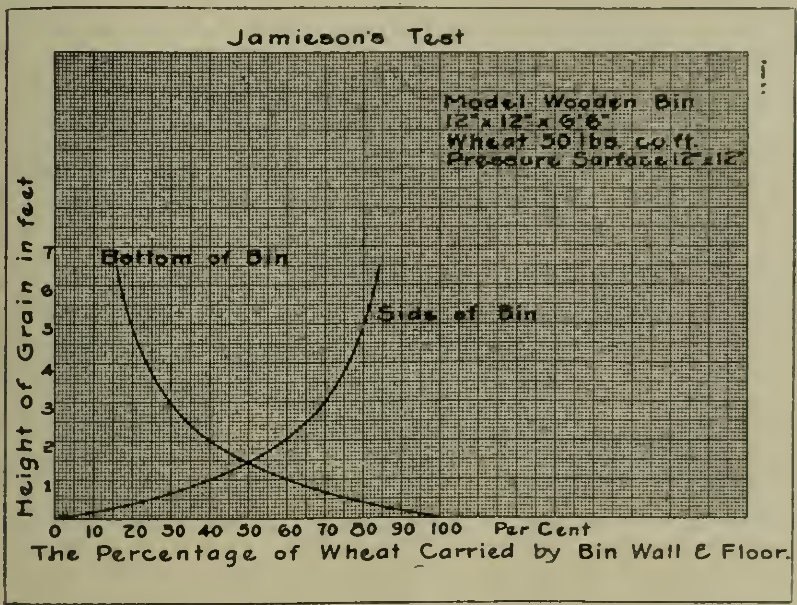


Fig. 14.

7. Tie rods decrease the flow but do not materially affect the pressure.

8. The maximum lateral pressures occur immediately after filling, and are slightly greater in a bin filled rapidly than in a bin filled slowly. Maximum lateral pressures occur in deep bins during filling.

9. The calculated pressures by either Janssen's or Airy's formulas agree very closely with actual pressures.

10. The unit pressures determined on small surfaces agree very closely with unit pressures on large surfaces.

11. Grain bins designed by the fluid theory are in many cases unsafe, as no provision is made for the side walls to carry the weight of the grain, and the walls are crippled.

12. Calculation of the strength of wooden bins that have been in successful operation shows that the fluid theory is untenable, while steel bins designed according to the fluid theory have failed by crippling the side plates.

The information of this section, "Pressures of Small Grains," was secured from text on the *Design of Walls, Bins and Grain Elevators*, by Milo S. Ketchum, 2nd edition, 1913.

Building Out Rats and Mice.

The rodent menace costs the farmers and grain men in the United States millions of dollars each year. It has been estimated that each rat destroys from $2.00 to $4.00 worth of grain in a year, and the rat population is assumed to be at least equal in numbers to the human population. This waste may be reduced by discouraging and building out these pests. This may be accomplished by using concrete for foundation walls and floors and placing floor some distance—18 in. to 24 in.—above grade. Modern construction and the shelling trench have encouraged this height of floor above grade. This makes it more difficult for rodents to enter crib, because they must climb or jump up to enter crib.

Rat guards may be used to stop rodents from climbing. These are shown in *Fig* 15, *b* and *d*. A piece of galvanised sheet metal is set under wall plate, and extends outward and downward for 3 in. or 4 in.

A further precaution against rats burrowing is made by extending a step footing or building a ledge of concrete, 4 in. to 6 in. outward from foundation wall. A rat in burrowing will become discouraged and give up when meeting an obstruction of this kind. (*Fig.* 15.)

It is recommended that the ends of frame crib be enclosed with tight or matched siding. This prevents rodents climbing up between door and cribs, where doors are open.

The shelling trench should be screened with heavy hardware wire cloth, which should be placed on a hinged frame that closely fits opening. This door may be opened for access of cats or ferrets.

In the cement stave type of crib rats are kept out by the $\frac{1}{4}$-in. rods which run lengthwise through the openings. Some concrete block cribs have wire mesh embedded in the concrete, which effectively prevents rats and mice from crawling in through the openings provided for ventilation.

Floor Construction for Crib and Granaries.

While wood has been used for crib floors, it is not permanent and will not stop rodents. The more permanent floor made from concrete is advised. This may be made with sheller trench as shown in *a*, *Fig.* 15, or of solid concrete, with fill under, or a combination tile and concrete fill.

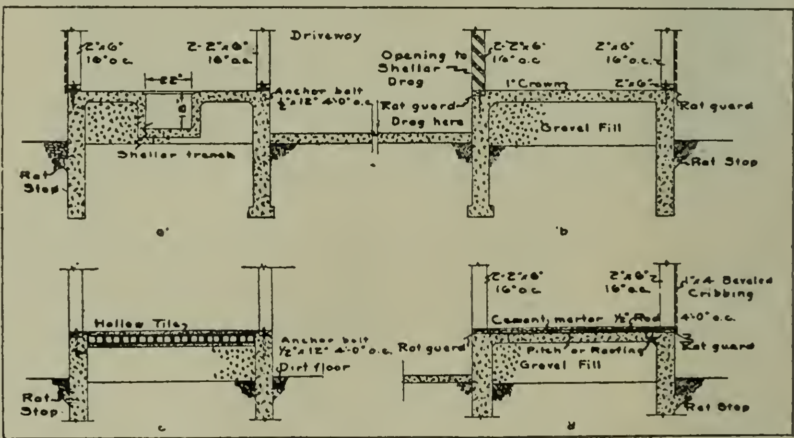


Fig. 15. See Text.

The floor may be built of two courses and pitch placed on first course, then depositing a second course of rich cement mortar. Roofing paper also serves the same purpose. Several methods of fastening sills are shown in *Fig.* 15.

The floor construction for small overhead grain bins is made by using matched flooring over joists, as shown in section *Fig.* 9.

Shelling Trenches.

The shelling trench may be made either as shown in *a* or *b*, *Fig.* 15. The former consists of a rectangular or square trench, extending from end to end of crib. It is large enough to receive the sheller drag. The depth is usually 18 in., with a width of 20 in. to 24 in. The disadvantages are the difficulty in placing the drag in trench and the harbour made for rats, if not thoroughly guarded. A large part of the corn will fall directly into the trench. It also serves as a ventilating duct.

The provision for drag along inside of crib, as shown in *b*, *Fig.* 15 is extensively used for shelling. The boards are removed from the outside. The drag may be moved from one crib to the other without resetting sheller. Furthermore, it may be used for removing ear corn for feeding purposes.

Its disadvantage is the difficulty of making it rat-proof. Rats will climb up on vehicles or implements and jump to these openings.

Ventilating Corn Cribs.

The cupola or aerators placed on roof will allow the air to pass out from cribs and bins. The air will rise upward through grain to replace the air removed.

Louvre windows may be placed in gables or cupola or gables of crib for air circulation. These should be screened on outside with small mesh hardware cloth to keep out sparrows.

Additional ventilation may be secured by utilising the sheller trench for an air passage and placing vent shafts (*Fig.* 16) over this at intervals. The natural draught or a forced draught and heat may be used. Another means of allowing air to circulate through the mass of corn is placing vent ducts (*Fig.* 16) across the crib. These ducts are made the width of crib and they are placed horizontally across through the corn. This opens the interior of crib to air circulation.

Rain and Snow.

Under ordinary conditions, rain and snow will not enter a well built crib. It is advisable, however, to provide a slight crown in floor for any moisture accumulating from rain, snow, or soft corn, to flow out. Provision is made in *a*, *Fig.* 15, by raising plates by shimming up with slate or pieces of hollow block. This allows moisture to pass out and at the same time protects plate from decay or fungus growth.

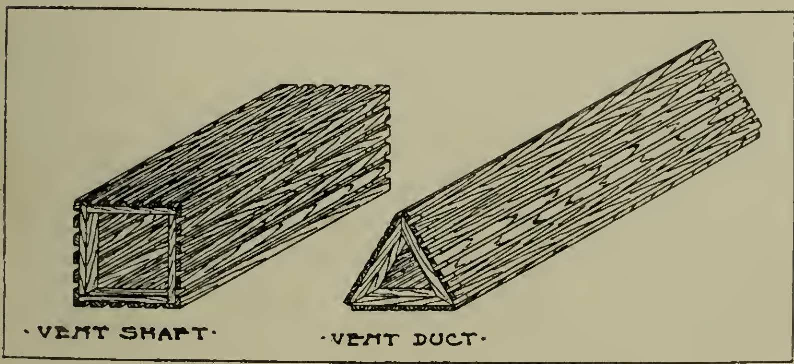


Fig. 16.

In *b*, *Fig.* 15, the inside plate is set in or partially embedded in concrete floor. The plate should be treated with creosote as a protection. The outside plate is shimmed up with slate or tile.

In States where blizzards are prevalent, the top two or three feet of the crib is made tight, so that snow will not blow on the corn after it settles.

Location of Crib.

The cribs should be located with reference to barns and feed lots, in an accessible place to farm yard, and, if possible, in full view from service part of house. While conditions will govern, it is desirable to have axis of rectangular cribs extend north and south, because of the sunshine advantage.

Drying Ear Corn in Crib.

Artificial means of drying ear corn have not been developed except for emergencies. A forced blast of heated air has been tried with fair success. This means is expensive because the initial cost of drying equipment is great.

A method recently adopted, of placing a drying rack under roof, by a material company, has merit and should be recognised. This consists of a grating built between roof and small grain bins. The corn is allowed to remain on grating for several days, which serves as a dryer. The heat from the roof and air passing up through rack will remove considerable moisture, before corn is finally dropped into bins. This permits the corn to dry on rack from a few days to a week before the corn is dropped to bins below. Another claim is the corn may be gathered a week to ten days earlier by using this dryer.

CEMENT NOTES.

By Our Special Contributor.

ROTARY KILN ECONOMY.

Economy in manufacture is a matter that is continuously engaging the attention of cement makers, and it is repeatedly found that fuel consumption in kilns offers more scope for economy than any other department. In their early stages, rotary kilns were worked on a rule-of-thumb basis and considerable importance attached to the kiln attendant or rotary kiln " burner," as he is styled. This feature has not altogether disappeared, but in the majority of works, scientific supervision of rotary kiln calcination is adopted and temperature records, flue gas analyses, etc., are continuously made so that the thermal efficiency of the burning operation can be calculated. Such technical supervision has no doubt helped appreciably in the reduction of fuel consumption in many cases and no manufacturer can afford to be without it, but even so, it must be admitted that the thermal efficiency of the rotary kiln at its best is not a subject for congratulation.

Following established steam boiler practice, the efficiency of a rotary kiln is most conveniently shown by a heat balance sheet, and this means of presentation is preferable to a mere statement of thermal efficiencies in percentages, because of the absence of any agreement as to the basis for the calculation. In boiler practice, the efficiency figure expresses the relation between the heat supplied in the form of heat units from the coal and the heat given out in the form of steam, but in rotary kiln theory, the issue is not so simple because of the doubt in measuring the heat given out. This difficulty will be appreciated more readily after consideration of the heat distribution.

One of the earliest attempts to analyse the heat distribution in rotary kilns was published by H. S. Spackman in America in 1905, and subsequent investigators have adopted the same fundamental considerations.

The heat introduced into a wet process rotary kiln is employed in the following operations :—

(1) Evaporation of water from slurry.

(2) Decomposition of calcium carbonate in slurry.

(3) Heating the water and carbonic anhydride from the slurry and the products of combustion of the coal to the temperature at which these gases leave the kiln.

(4) Heating excess air used for combustion to the temperature of the chimney gases.

(5) Radiation of heat from kiln.

(6) Heating clinker to the temperature at which it leaves the kiln.

A consideration of the above will lead to the conclusion that the only essential item is No. 2, viz. decomposition of calcium carbonate in slurry, because all other items could, under ideal conditions, be reduced to zero. On this basis, therefore, the efficiency of a rotary kiln might be expressed as the relation between the heat supplied to the kiln and the heat required to decompose the calcium carbonate in the slurry. The heat supplied to a rotary kiln is usually about 6 cwt. of coal (of good quality) per ton of clinker, and the amount absorbed in the decomposition of calcium carbonate is about 1·5 cwt., so that on this basis the efficiency is only 25 per cent.

It may, however, be claimed that when the wet process is adopted, the evaporation of water is an essential feature of the process and should accordingly not figure as a loss of efficiency. Evaporation of water from a slurry containing 40 per cent. of water requires an amount of coal equal to about 1·7 cwt. per ton of clinker produced, and therefore if the essential processes be taken to include both decomposition of calcium carbonate and evaporation of water (up to 40%), the usual efficiency of a rotary kiln becomes 53 per cent. This is a figure not comparable with boiler efficiency, where 60 to 70 per cent. is expected in daily running, and the suggestion already made that kiln fuel consumption should be a fruitful field for economy is thus confirmed.

It remains to consider the losses of heat that lead to this low efficiency, and the most important is that referred to in the third item of the heat analysis that has been mentioned, viz. heat in chimney gases. The temperature of the flue gases leaving a wet process rotary kiln is usually between 600° F. and 1000° F., and the amount of heat so lost averages about 1·5 cwt. of coal per ton of clinker. Under certain circumstances it is worth attempting to recover this waste heat by interposing a steam boiler between the kiln and the chimney, but if this is not done, any device or manipulation of the kiln to reduce the flue gas temperature will yield great economy.

Another source of heat loss is in the use of any appreciable excess of air above that required for combustion. Such air has to be heated to the temperature at which the gases leave the kiln, and therein lies the loss. The proportion of excess air is, of course, readily ascertained by analysis of the gases leaving the kiln. In ordinary practice, the loss of heat due to excess air rarely exceeds 0·2 cwt. coal per ton of clinker.

The loss through radiation of heat from rotary kilns is practically impossible of exact determination, as it involves a knowledge of the temperature of every part of the kiln shell, the cooler shell, and their connecting parts. Moreover, even if this data was obtainable, there is some doubt as to the exact formula to apply under the varying conditions of air currents, nature of radiating surfaces, etc., which exist in rotary kiln plants. The radiation loss is usually taken as the difference between the heat supplied to the kiln and the heat used and known to be wasted in other directions. Probably the loss is equivalent to about 1 cwt. of coal per ton of clinker in the average kiln. Although the loss can be mitigated to some extent by insulation of the kiln shell and cooler shell, this is a remedy which does not seem to have been sufficiently successful to warrant general adoption.

The remaining source of heat loss to be considered is that in the clinker leaving the kiln. At a temperature of 2400° F. clinker as it leaves a rotary kiln holds an amount of heat equivalent to about 1 cwt. of coal per ton of clinker, but in the majority of cases a portion of this heat is recovered by using the clinker to heat the air required for combustion. The amount so recovered ranges from 50 to 75 per cent. of that available, and thus the net loss in clinker leaving the kiln is from ¼ to ½ cwt. per ton of clinker.

The distribution of the heat supplied to a wet process rotary kiln may now be analysed as follows :—

	Cwts. coal per ton of clinker.
1. Heat absorbed in evaporation of water	1·7
2. ,, ,, ,, decomposition of calcium carbonate	1·5
3. Heat wasted in chimney gases . . .	1·5
4. ,, ,, excess air	0·2
5. ,, ,, ,, radiation (by difference)	0·8
6. ,, ,, ,, hot clinker	0·3
Total coal consumed per ton of clinker (cwts.)	6·0

A Reinforced Concrete Building in Japan.

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

In response to a very general request we are re-starting our Questions and Answers page. Readers are cordially invited to send in any questions. These questions will be replied to by an expert, and, as far as possible, they will be answered at once direct and subsequently published in this column for the information of our readers, where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—Ed.

Question.—A. H. B. writes :—With reference to the November copy of CONCRETE, *there is on page* 710 *a simple example of reinforced concrete design by O. Faber, Esq., O.B.E.*

The design is for a ferro-concrete water tank and on page 712 *the following remarks occur :—*

"*The author recommends for small tanks a nominal stress of* 8,000 *lb. per sq. in. and* a percentage of steel not exceeding 1 per cent. of the concrete by volume.

* * *

"*Now up to the point when the concrete cracks, the concrete and steel will act together, the steel, however, taking fifteen times as much stress as the concrete owing to its higher elastic modulus and being therefore equivalent to fifteen times its area of concrete.*"

It is difficult to see why a limit of 1 *per cent. of steel has been laid down by the author, though I have no doubt that the rule is sound, and I do not see that any logical reason has been given by him in his example.*

Apparently the limit of stress in the concrete is the more decisive factor, and a variety of combinations of concrete and steel will satisfy any limit laid down.

For example, assuming that concrete may not be stressed more than 70 *lb. per sq. in., and that a section subjected to a pull of* 8,000 *lb. is under consideration ; then the equivalent area of concrete required would be* $\frac{8000}{70} = 114$ *sq. in.*

When steel is used it replaces a certain amount of concrete. Theoretically an infinite number of combinations of steel and concrete can be made such that the stress in the concrete does not exceed 70 *lb. per sq. in., e.g.,*

1 *sq. in. of steel*	99 *sq. in. of concrete*
2 ,, ,, ,, ,,	84 ,, ,, ,,
3 ,, ,, ,, ,,	69 ,, ,, ,,
&c.	*&c.*

It is by no means evident on what basis a limit of 1 *per cent. of steel has been laid down. It seems to be a question of the comparative cost of steel and concrete.*

I have done a good deal of ferro-concrete work in a small way in India, and am much interested in the subject, so I would be very much obliged for an explanation.

Answer.—I quite agree with your correspondent's contention that there are an infinite number of combinations of steel and concrete which shall satisfy the condition that the concrete tensile stress shall not exceed 70 lb./in.^{2}

Of these, however, those with very little steel are ruled out because the steel must be able to take the whole tension (at a stress of about 16,000 lb./in.^{2}) if the concrete should crack.

Following your correspondent's figures $\frac{1}{2}$ sq. in. of steel and $106\frac{1}{2}$ sq. in. of concrete would limit the concrete stress to 70 lb./in.^{2}, with a tension of T = 8,000 lb., but if the concrete cracked, clearly the steel stress would be 16,000 lb./in.^{2}, and as any *less* steel would give a higher stress, this clearly represents the *least percentage.*

The limit in the other direction is governed by economy.

Clearly 1 sq. in. of steel is much more costly than 15 sq. in. of concrete. Actually, taking a foot length in both cases, the relative costs are about

Steel 3·4 lb. @ $2\frac{1}{4}$*d.* = 7·6*d.*

Concrete—$\frac{15}{144}$ cu. ft. @ 2*s.* = $2\frac{1}{2}$*d.*

the steel therefore being about three times as costly.

The most economical solution is therefore :

Solution A—$\frac{1}{2}$ sq. in. of steel and $106\frac{1}{2}$ sq. in. of concrete.

The solution given by my rule in the November issue was :—

Solution B—1 sq. in. of steel and 99 sq. in. of concrete.

This differs very little in cost, as may be seen :—

			Cost per ft. run.
Solution A—			
			d.
Steel . .	1·7 lb. @ $2\frac{1}{4}$*d.*	=	3·8
Concrete .	$\frac{106\frac{1}{2}}{144}$ cu. ft. @ 2*s.*	=	17·7
			21·5
Solution B—			
			d.
Steel . .	3·4 lb. @ $2\frac{1}{4}$*d.*	=	7·6
Concrete .	$\frac{99}{144}$ cu. ft. @ 2*s.*	=	16·5
			24·1

I think probably Solution B with twice the steel area is worth this very little additional cost.

This will give reduced adhesion stresses, and tend to prevent shrinkage stresses during setting.

I am obliged to your correspondent for his remarks, which have been helpful in enabling me to give a clearer explanation.

Perhaps the following is a useful summary of the matter :—

(*a*) For safety, the steel should be capable of taking the whole tension at a stress not exceeding 16,000 lb./in.^{2}

(*b*) For water-tightness, the concrete tensile stress should not exceed somewhere about 60–70 lb./in.^{2}

(*c*) There are an infinite number of solutions which satisfy (*a*) and (*b*) but making the steel area sufficient to take the total tension at a stress of 8,000 lb./in.^{2} and making the concrete area 100 times the steel area is probably one of the best solutions. O. F.

Question.—J. S. writes :—I am considering the desirability of forming a flat reinforced concrete roof on bungalow rooms, not exceeding 14 *ft.* × 16 *ft. I was thinking that it could be formed with some form of reinforcement that does not require forms or girders ; what reinforcement would you recommend ? Could you say what would be the approximate cost of such a concrete roof in comparison to a roof of wood, gutters and tile in the ordinary way. Are there any objections to a roof of this description ?*

Answer.—A 6-in. flat roof with ½-in. rods at 6-in. centres in both directions, half bent up over supports, would probably give all that is required.

This may cost about 25s. a square yard. If well built and designed, there would be no objections.

Unless you are familiar with these matters, we advise you to obtain a design from a competent engineer.

Question.—J. G. writes :—In all text-books on reinforced concrete it is stated that :—

The compressive stress in a beam = tensile stress.

In view of the fact that the section of an R.C. beam is not symmetrical about the neutral plane I cannot understand why this can be so and why it is not the case that :—The moment of the compressive stress = the moment of the tensile stress. Then R = the sum of these moments and would give quite different results from R = total tensile stress = lever arm or *R = total compressive stress × lever arm, which latter is the method used by text-books.*

I would greatly appreciate an explanation of this my difficulty by your expert who deals with such questions.

Answer.—Your correspondent's difficulty arises from his confusion of terms. He is using the word stress in a loose way to mean two quite different things.

Stress is a measure of the intensity of the force per unit area to which a member may be subject, and is measured in pounds per square inch, tons per square foot, or any other unit having a force in the numerator, and an area in the denominator.

Force, however, is the total force acting, without reference to its intensity, or the area on which it acts, and is measured in lb., tons, etc.

Your correspondent uses the word stress for both.

The first statement—that compressive *stress* in a beam = tensile *stress*—is nonsense, nor is it true to say that all text-books on reinforced concrete commit themselves to this statement.

The correct statement is that the total compressive *force* is equal to the total tensile *force*—sometimes called the total compression and total tension respectively, and therefore the same resistance moment is arrived at whichever of these is multiplied by the lever arm.

NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

Calcul Pratique des Poutres Continués en Béton Armé. (Practical Design of Continuous Beams of Reinforced Concrete.) By G. Magnel, of Gand University.

Messrs. Van Rysselberghe & Rombaut, Publishers, Gand. Price 30 fr.

This book is of especial inteiest to those who consider it necessary for reinforced concrete engineers to be able to calculate moments in continuous beams and who are not satisfied with arbitrary and incorrect guesses, which may give results which a large factor of safety may in ordinary cases render safe, but which become dangerous in special cases (as with unequal spans) and are uneconomical always when the large factors of safety which they necessitate are taken into account.

The method employed by the author is that of influence lines, which makes the results of particular interest to the present reviewer, because the author arrives by entirely different methods at results which agree entirely with his own in all the cases where he has compared them.

The author shows that the influence line for moments in a cantilever is a triangle having its apex at the support, so that the farther the load is therefrom, the greater is the moment produced by it. He then shows that for uniform loads, the area of the influence diagram gives the moment.

The same principle is then applied to simply supported beams, the influence curve for the moment at midspan being a triangle erected on the span.

The author then explains Maxwell's theorem of reciprocal deflections and from this deduces the fact that the influence line of the reaction at any support in a continuous beam produced by a load anywhere in any span of the beam is the same (to some definite scale) as the elastic curve (or line of deflections) produced by the reaction on the continuous beam.

Similarly he shows how the influence line of moments at a point A, due to loads anywhere in a continuous beam, is the same as the elastic curve produced by applying a moment at the point A.

These important and interesting results much simplify for the author the drawing of his influence lines, which he then proceeds to give to scale in eleven large plates, intended for practical use.

These apply in the first cases to equal spans and moments of inertia and ignore the stiffness of columns.

Subsequently plates dealing with stiffness of columns are given, which give results entirely in accord with those worked out by the present reviewer.

Lastly plates are given applying the results to cases of unequal spans and unequal moments of inertia.

Apart from the very great interest attaching to the whole treatment, it will be important to consider to what extent the results are likely to offer methods which would be preferable in practice to existing methods of arriving at the same results, and the reviewer's views on this are as follows. He thinks that for uniform and symmetrical point loadings (whether the stiffness of columns is to be ignored or not) it is much simpler to use the moment curves given in his second volume of *Reinforced Concrete Design*, but that for rolling or other unsymmetrical point loads, the new method is a great advance on anything at present in use.

As regards the last portion, dealing with unequal spans and varying moments of inertia, the method given involves the drawing of an influence line for each special case, according to rules laid down.

The work involved here is so great as to make it applicable only to the checking (after design) of some work of extraordinary importance.

The method also suffers from the defect that the moments of inertia of all the spans need to be known before a start can be made (this probably applies to all accurate methods), but more seriously from the defect that the moment of inertia has to be constant over each span, which it would not be, even approximately, particularly when the spans vary much.

In conclusion, this work is one of real interest and should be studied by all serious students. O. F.

Der Eisenbetonbau (Reinforced Concrete Construction). By C. Kersten, of the Building School, Berlin.

W. Ernst & Sohn, Publishers, Berlin, 99 Mk.

This volume of 358 pages, which, however, only measures 4¾ in. × 7¼ in., is intended to cover the whole field of design and construction.

No doubt it will be very useful to students in German technical colleges who need to acquire some general acquaintance of both in very little time.

We are told it is intended for schools and for practice, and here we respectfully submit the author is ill-advised in attempting to make one book serve both, and in our view the result suffers greatly from attempting to reconcile these two objects.

In our opinion a student (perhaps not a German student) would only be confused by the mass of complicated formulæ and tables, in most cases insufficiently explained.

At the same time the work is hardly suitable for practical design, since, for example, there are no curves for the rapid derivation of commonly required quantities.

We think it is much too complicated for students, and too sketchy to be really useful for practice.

The author clearly understands his subject, and very likely the work would be a useful record of, and supplement to, his own lectures.

To us, the smallness of the pages, the poor paper, and absence of a stiff cover detract much from the usefulness of the book. O. F.

Report on Heat Insulators by the Engineering Committee of Food Investigation Board, Department of Scientific and Industrial Research.

H.M. Stationery Office, Publishers. Price 3/- net.

This deals chiefly with the properties of such good insulators as cork, slag wool, wood, charcoal, etc.

The report is a very valuable one to constructors of the insulation to cold storages.

As the subject lies rather outside our scope, we will not deal with it except to mention that the conductivity of concrete was given as 8·5 B.T.U. per sq. ft. per 1 in. thickness per degree Fahr., and it is mentioned that the conductivity of cement is much less, and that of stones much more. O. F.

"Brucken in Eisenbeton." ("Reinforced Concrete Bridges.") By C. Kersten.

Wm. Ernst & Sohn, Berlin. 42 Mk.

We gather that the author was previously Chief Engineer and is now Senior Lecturer in the Building School at Berlin, which, of course, gives him acquaintance with both the theoretical and practical sides of the subject matter.

The present work, we gather, is Part 1, and deals with slab and beam bridges, whereas Part 2 deals with arched bridges. The work abounds in excellent little drawings and sketches, of which there are 605, which illustrate in a very complete way—not only practically every type of reinforced concrete bridge—but also in many cases gives details of the reinforcement and shows very clearly all the various details, such as expansion joints. The various photographs also in many cases show the centering and steel fixed in position and details are given of the falsework. This first volume is divided into two parts, the first of which deals with the general arrangement of all the different kinds of bridges and the practical points in connection with them, while the second portion deals entirely with calculations. This portion also is very well written and gives little bending moment diagrams to illustrate the various cases together with sufficient details of the reinforcements to make the calculations clear.

In conclusion the work is undoubtedly one which may be recommended to any one making a special study of reinforced concrete bridges, and to whom the fact of its being written in German is not an insuperable objection.

O. F.

SOME EXTRACTS FROM THE FOREIGN PRESS.

THE USE OF PUZZOLANA IN MARINE WORK.

A SERIES of experiments on a large scale and extending over a long time has just been published by L. Luigi. They show that the use of puzzolana for marine work is more favourable than is often supposed, and the author has drawn the following conclusions from his experiments :—

1. In mixtures of puzzolana and lime used for marine work, the best proportions are one volume of lime putty to three volumes of the puzzolana.

2. It is a matter of indifference whether the aggregate is washed with fresh water or sea water.

3. The use of 1–2 cwts. of cement to each ton of mortar has the advantage of hastening the setting and increasing the final strength of the mortar.

4. In concretes made of puzzolana and lime with a stone aggregate the best proportions are 1 cu. yd. of the mortar to 4–10 cu. yds. of aggregate.

5. Concrete blocks made of the foregoing mixtures should be kept in the forms for a week, then covered and watered daily for two months before being taken into use. If, however, cement is also used—as in a mixture consisting of 2 cu. ft. of lime, 4 cu. ft. of puzzolana, 7 cu. ft. of aggregate and 50 lb. of Portland cement—they need only be kept in the forms for two days and may be used in a month, if kept properly wetted in the meantime. One set of experiments seems to show that such a mixture could be put in the sea within twenty hours of its production without it being damaged. —*Revue des Materiaux de Construction.*

PLANS FOR A NEW BRIDGE IN DENMARK.

There were forty-four entries in a competition for the best method of bridging an arm of the sea between Aalborg and Norressund in Denmark, and the competitors are in all parts of the world.

The space to be bridged over is 1,700 ft. long, and the foundation is 80 ft. of sea mud, so that iron supports are undesirable. Of the forty-four entries, only seven specified concrete.

The prizes were given to the following :—(i) Brückenbavanstall, Gustavsburg; (ii) Jutehoffnungshütte, Sterkrade, with Monberg and Thorsen, Copenhagen; and (iii) A. Bollinger, Lucerne.

Of the reinforced concrete structures, only two were considered by the judges, and both these made use of Dr. Emperger's patented "covered cast-iron" method, which was first used in the construction of the Schwarzenberg Bridge in 1913.[1]

This form of structure is the only one in which the lightness and general character of ironwork bridges can be combined with the advantages possessed by concrete.—*Beton ü. Eisen.*

GARDENER'S FRAMES IN CONCRETE.

Concrete has obvious advantages over wood in the construction of garden frames, especially if the concrete frames are made in sections so that they may be readily assembled and dismantled.

In some frames made at Ströbitz near Kottbus, the concrete is reinforced with gas-piping, which keeps the interior of the frames warm by providing cavities in the walls. The corners are reinforced by angle irons. The concrete mixture is quite lean—a 1 : 6 mixture being satisfactory.

There is nothing new in using concrete for making garden frames, but the use of reinforcement in the manner indicated is a great improvement over mass-concrete without reinforcement.—*Zement.*

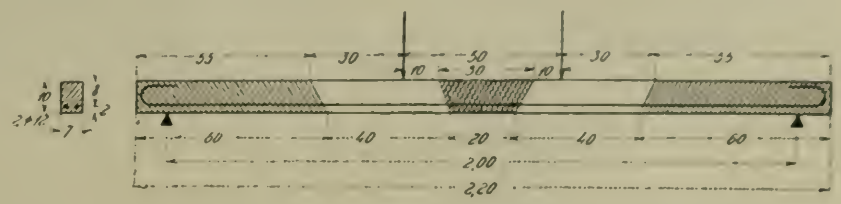
TESTING CONCRETE ON THE SITE.

One of the most serious objections to the customary methods of testing cement and concrete is the great length of time required. The result is that a concrete

[1] See *Concrete and Constructional Engineering*, vol. viii, pages 491 and 540.

structure may be so far advanced that it is impracticable to pull it down when the results of the tests are received, whereas if the tests could be completed in a week there would be far less difficulty.

Dr. Emperger has now shown that sufficiently reliable results can be obtained for all practical purposes by making a test beam of suitable dimensions, but instead of making the whole beam afresh for each test he now cuts out the centre portion, leaving the greater part of the beam intact, and fills in the middle with the fresh concrete.



He suggests a beam of the dimensions shown in the illustration (in centimetres) only the portion between the vertical arrows (about 20 in.) being renewed, so that the material required for a test is only about 264 cu. in., though it is better to use more rather than less this amount. With care, accurate results can be obtained if only half this volume (the middle shaded portion of the illustration) is used.

The beam is tested in the ordinary manner by supporting it on two knife-edges and measuring the modulus of rupture when a load is applied at the middle by means of a third knife-edge.

The beam may be tested eight days after it has been re-made, and as the fresh portion may be withdrawn from the batch-mixer at any time, the test forms an adequate one for both the cement and the concrete.—*Beton ü. Eisen.*

THE SCOLTENNA BARRAGE.

The use of reinforced concrete is rapidly spreading in most civilised countries, and whilst earth embankments are sometimes cheaper for small works, and masonry is sometimes preferred for barrages more than 160 ft. high, there is ample scope for intermediate barrages, 90–160 ft. in height, for which reinforced concrete is unquestionably the best material. For large barrages less than 160 ft. in height, reinforced concrete provides the greatest amount of security with the least expenditure, as it permits the use of arches and other relatively light forms of construction without requiring any unnecessarily large quantities of material. This is important in these days, when the transport of materials is so expensive an item.

Among many interesting dams which have been built in Italy, for obtaining power from the great watersheds of that country, few are more interesting than the one at Scoltenna in Modena, which supplies the water for a hydro-electric installation at Ponte Strettara. The area in which this reservoir is situated is a particularly wet one, with an average rainfall of 20–30 in. The reservoir has a capacity of 800,000 cu. yds., one-third of which suffices for the riparian rights of the district. A channel 5,500 yds. in length, of which 4,400 yds. is underground, carries the water to a charging basin in which is the 5 ft. pressure pipe.

The water supply is sufficient to enable the turbines to produce 30 million kilowatt hours per annum.

The more important details of the reinforced concrete work are shown in the accompanying illustrations, from which it will be seen that the dam wall is 78 ft. high and 250 ft. in length, and that it is composed of eight arches. The foot of the dam is provided with a catch-basin 6–8 ft. deep, which receives the shock of the rushing water, and affords some protection to the foundations.

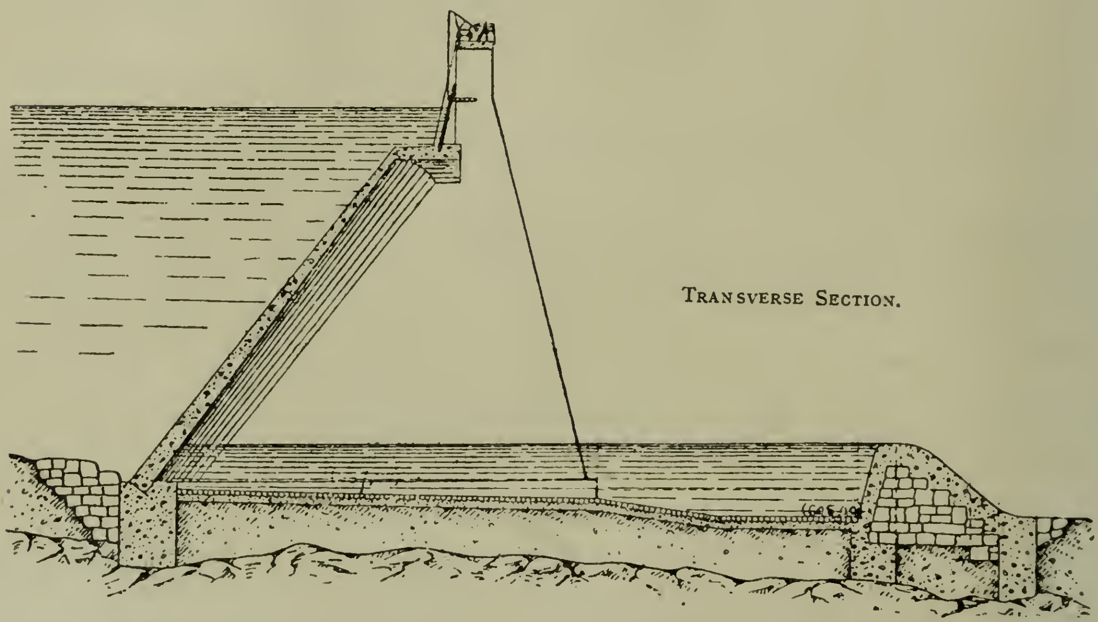
The walls supporting the arches are inclined in the ratio of about 40 degrees on the inlet side and of about 15 degrees on the outlet side. These walls are 32 ft. apart, and their thickness varies from 8 ft. at the base to 5 ft. 6 in. at the top. The thickness of the arches varies from 3 ft. 4 in. at the base to 16 in. at the top.

The calculated resistance of the walls to the pressure of the water is 116 lb. per sq. in. on the outlet side, and 49 lb. per sq. in. on the inlet side.

The solid rock was reached at so small a depth that complex foundations were unnecessary.

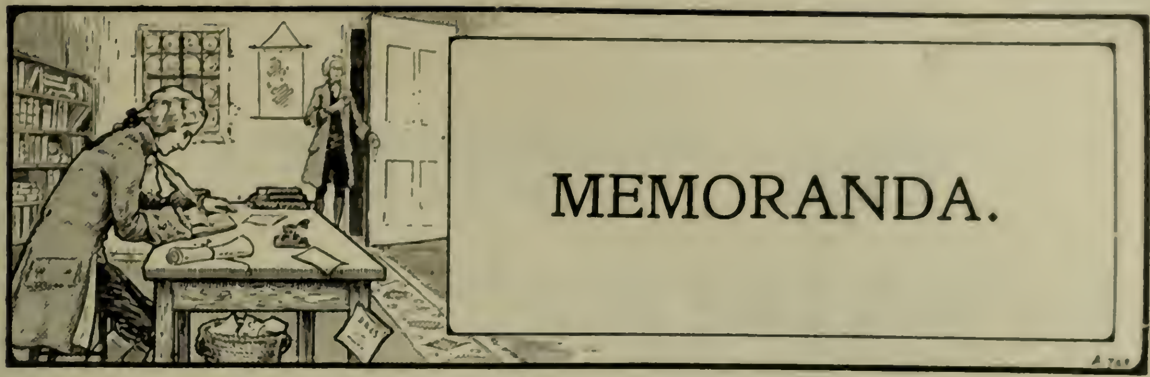
The reinforcement of the arches was given the form shown in *Fig.* 4, so as to allow for wide variations in temperature.

The construction was started by deviating part of the water during the summer, and so enabling the foundations to be built without inconvenience, but an exceptionally stormy autumn delayed further work, and destroyed part of the centre barrage before the concrete was properly set. With this exception the work proceeded rapidly, and the structure has proved of ample strength.—*Le Génie Civil.*



Transverse Section.

View Showing finished Upstream side of Dam.



MEMORANDA.

Memoranda and News Items are presented under this heading with occasional editorial comment. Authentic news will be welcome.—Ed.

Strength Tests on Pre-Mixed Concrete on Detroit Street Railways.—The following particulars are taken from *Engineering News Record* from an article by Mr. W. R. Dunham, Jr. :—

Concrete mixed overwet at central mixing plant was used for the base of the new track construction of the Detroit Municipal Railway Lines. Strength tests were made during the work and show remarkably consistent and high results.

In order that the work could be carried on with the requisite speed to ensure its completion in the time assigned, it was necessary that the concrete be mixed with an excess of water, and this was also thought to be desirable in order that the mixture would flow around the steel ties, thus thoroughly embedding the ties and rail bases in a monolith of concrete. Some tests made on the concrete are given here to show the compressive strength of concrete mixed to the consistency of pea soup. Exact percentages of water content are not available. There are included tests made from samples cut out of the work as actually laid, and from samples taken each day from the mixers. These latter samples were taken in 6-in. cardboard cylinders and tested at the ages as given. At the age of 40 days, blocks were cut from the concrete monolith at the locations where the concrete from which the samples were taken had been deposited. These were dressed to size and tested. Twelve sample blocks were made in the yards using the same aggregate, sand and cement, and kept moist, six of these were tested at the age of 81 days and six at the age of 91 days.

It will be noticed that the samples showing the least strength at seven days developed about the same strength

Table I—Summary of Tests of Concrete Foundation.

Test No.	Compression Strength, Lb. per Sq. In. 7-Day	28-Day
1 . . .	1,689	2,949
2 . . .	1,373	2,331
3 . . .	1,252	1,846
4 . . .	1,595	2,125
5 . . .	1,192	1,905
6 . . .	1,760	2,390
7 . . .	1,959	2,086
11 . .	1,440	2,397
12 . . .	1,516	2,500
13 . . .	1,831	1,945
P-30. . .	1,007	2,033
P-31. . .	*675	*2,750
P-32. . .	990	2,260
P-34. . .	945	2,462
P-35. . .	950	2,032
P-36. . .	837	1,965
P-37. . .	1,200	2,480
Average .	1,317	2,262
Average first ten samples	1,579	2,247

* Least at seven days, next to highest at 28 days.

Table II.—Poured Specimens Compared with those cut from Structure.

	(Compression, Lb. per Sq. In.) 7-Day	28-Day	40-Day
Moulded in Cylinders. P-30	*1,007	*2,033	M-3,411 (Cut from track slab.)
P-31	*675	*2,750	M-2,388
P-32	*990	*2,260	M-2,785
P-34	*945	*2,462	
P-35	*954	*2,032	
P-36	*837	*1,965	
P-37	*1,200	*2,480	
Average .	944	2,283	2,861

* Poured. M Cut from slab.

Table III.—Test of Samples made at Yard.

81 Days	91 Days
2,972	2,454
2,609	2,644
2,328	2,450
2,229	1,923
2,083	2,179
1,322	1,968
Average 2,257	2,270

at twenty-eight days as the other samples; and that the sample developing the least strength at seven days was the next to the highest at twenty-eight days.

Samples cut from the base as laid at the locations from which the cylinders were filled give strengths as noted in Table II compared with samples taken from mixer.

Tests of samples made at the yard using same proportion of aggregate and slag and same cement, and kept moist while curing, are given in Table III.

A Concrete Water Tower.—A concrete water tower has recently been erected at Langstaff, Ont., for the Toronto Municipal Farm, the work being carried out by prison labour.

The tower is 51 ft. high from floor to roof, and has an ornamental wall and a 12-ft. ornamental tower on the roof. The outside diameter is 18 ft. and the wall thickness is 18 in. at bottom, 15 in. halfway, and 12 in. at top. The foundation consists of a 4 ft. thick slab resting on a mattress of weak boulder concrete 36 ft. in diameter, this form of foundation was necessary owing to the nature of the soil.

The reinforcement consisted of old railway rails and scrap farm machinery in base, $1\frac{1}{8}$ in. round steel uprights in walls and steel rings varying from $1\frac{1}{8}$ in. round at 4 in. centres at bottom to $\frac{5}{8}$ in. round at 10 in. centres at top. As will be seen from the accompanying illustration, an ornamental castellated appearance was aimed at and we understand was obtained at a very slightly increased cost.

A Concrete Water Tower at Langstaff, Ont.

The walls for the tower were poured, wooden forms 4 ft. high being used for the purpose. A very liquid mix of 1 : 2 : 4 was used. After every 4 ft. of pouring blocks 4 in. by 4 in. were set into the concrete and removed three days later, and the groove was thus formed. The surface of the concrete was thoroughly chipped off to a depth of 1 in., leaving a ragged surface. Just before pouring again, this was treated with a 10 per cent. solution of hydrochloric acid, thoroughly washed and well dusted with dry cement for commencing the new pouring; the liquid cement was scratched about upon the old concrete with hoes in order to bond the new concrete well to the old.

Super-cement was used for the wall and bottom of the tank.

TRADE NOTES

The "Champion" Block and Slab Maker.—In our November issue we published particulars of this machine, but owing to lack of space were unable to show the accompanying illustrations. *Fig.* 1 shows the machine ready to receive the concrete, and *Fig.* 2 shows the finished block and the moulding box in a position to facilitate the removal of the stone.

On pressing the foot treadle the mould box is automatically retained in top position until the stone is removed and a new puller is placed in position.

Fig. 1.

Fig. 2.

The "Champion" Block and Slab Maker.

Full particulars of these machines can be obtained from Messrs. R. H. Kirk, & Co., Collingwood House, St. Peters, Newcastle-on-Tyne.

TENDERS INVITED.

Glossop.—The Glossop Town Council invites tenders for alterations and extensions at the sewage outfall works, including the extension of detritus tanks, the conversion of existing filter beds, the construction of storm tanks, bacteria beds, humus tanks, etc. Forms of tender may be obtained from the Engineers, Messrs. Brady & Partington, Town Hall, Chapel-en-le-Frith. Tenders to be delivered by February 15.

Conisbrough.—Tenders are invited by the Urban District Council of Conisbrough for the erection of 32 houses of various types. Specifications, etc., may be obtained from Mr. H. Thirlwell, Borough Surveyor, Church Street, Conisbrough (deposit £2 2s.). Tenders are to be delivered by February 17.

Argentina.—The Ministry of Public Works of the Argentine Republic invite tenders for the supply of concrete mixers, excavators, and other plant, to be delivered by February 21. Further particulars must be obtained from the Department of Overseas Trade, 35 Old Queen Street, S.W.

Bombay.—Tenders are invited by the Government of Bombay for the construction of a sewage scheme for an area with 10,000 inhabitants, to be delivered by March 15. Further particulars may be obtained from the Superintending Engineer, No. 3 Project Division, Old Custom House Yard, Fort, Bombay.

TENDERS ACCEPTED.

Aberdeen.—The following tenders have been received by the Joint Committee of the University of Aberdeen and the North of Scotland College of Agriculture, for the brick and concrete work in connection with the erection of a 3,000-gallon reinforced concrete liquid manure pit and a 50-ton manure c* pit at the Rowett Research Institute :—C. McDonald & Sons, Dyce, £298 10s. ; J. McAdam & Sons, Ltd., Aberdeen, £316 3s. 1d. ; G. Hall (Trustees of), Aberdeen, £339 ; J. Scott & Son, Aberdeen, £3[illegible] ; A. Masson, Hardgate, £374 6s. ; G. Duncan & Son, Inverurie, £457 13s. ; R. Moir, Aberdeen, £515 ; W. Tawse, Torry, £550 ; G. Farquhar, Aberdeen, £615 10s. ; C. R. Building Constructions, Ltd., London, £669 10s.

Aberdeen.—The University of Aberdeen has accepted the tender of Messrs. James Scott & Son, Ltd., of Aberdeen, for the construction of a 100-ton capacity reinforced concrete silo at the Rowett Research Institute, Bankhead, for the sum of £584 6s. 4d. ; the time of execution is eight weeks. Other tenders received, with the time stipulated for erection, were as follows :—Melville, Dundas & Whitson, Glasgow, £629 17s. (for silo of different design) ; Melville, Dundas & Whitson, Glasgow (no time stated), £699 17s. ; M. Muir & Co., Kilmarnock (20 weeks), £726 17s. 3d. ; Kelvin Construction Co., Glasgow (10 to 14 weeks), £864 5s. 10d. ; Robert Moir, Aberdeen (32 weeks), £1,020 10s.

Brighton.—The tender of the Unit Construction Co., Ltd., of London, has been accepted by the Brighton Town Council for the erection of an additional building at the racecourse on the Hennebique system of reinforced concrete construction and for alterations to the grand stand at the racecourse, for the sum of £4,991.

Bury St. Edmunds.—The tender of Messrs. C. Maidwell & Co., Ltd., of Stowmarket, at £234 19s. 6d., has been accepted by the Bury St. Edmunds Town Council for the construction of a reinforced concrete floor and parapet to the bridge on the Mildenhall-Littleport main road. Other tenders received were :—E. Howes, Bury St. Edmunds, £237 6s. ; Clarke Bros., Mildenhall, £247 14s. ; H. G. Frost, Bury St. Edmunds, £248 ; Hinnels & Son, Ltd., Bury St. Edmunds, £315 6s. 6d. ; R. J. May, Norwich, £342.

Chiswick.—The Tender of Messrs. Peter Lind, Ltd., of Westminster, has been accepted by the Chiswick Urban District Council for the construction of a concrete culvert, for the sum of £9,985. Other tenders received were :—F. Cressy (Chiswick), £10,609 15s. ; Davidson & Sykes (Westminster), £12,710 ; Wimpey & Co. (Hammersmith), £13,920 ; Kirk & Randall (Westminster), £17,500 ; Walkerdine, Ltd. (London), £35,530.

Goole.—The Goole Urban District Council has accepted the tender of Messrs. Oates & Green, of Halifax, for the supply and delivery of 400 yards of 15-in. diameter glazed stoneware or concrete pipes.

Halifax.—The Halifax Town Council has accepted the tender of Messrs. George Greenwood & Sons (Halifax), at £1,885, for the construction of a concrete roof at the Park Road Bath.

Hendon.—The following tenders have been received by the Hendon Urban District Council for the construction of an open-air swimming bath (prices (a) are for a reinforced concrete bath) :—Harry Neal (Northwood), £4,271, (a) £4,271 ; A. L. & H. W. Chown (Northampton), £4,662 8s. 8d., (a) £4,862 8s. 8d. ; W. J. Parker, Ltd. (Westminster), £4,813, (a) £4,531 ; Porter & Little (London, E.C.), £4,841 18s. 11d., (a) £4,790 ; G. Munday & Sons, Ltd. (London, E.C.), £4,862, (a) £4,912 ; W. H. Garze & Sons (Kingston-on-Thames), £5,187 ; Holtum & Green, Ltd. (Finsbury), £5,200, (a) £4,988 ; T. Muirhead & Co., Ltd. (London, E.C.), £5,254 6s. 2d., (a) £5,036 6s. 2d. ; T. Shillitoe (London, N.), £5,300, (a) £5,150 ; Sabey & Sons (Islington), £5,379, (a) £5,525 ; D. R. Paterson, Ltd. (Camden Town), £5,418 9s. 4d., (a) £5,027 11s. 3d. ; C. Carter (Golders Green), £5,457, (a) £5,283 ; Wm. Moss & Sons, Ltd. (London, W.C.), £5,545, (a) £5,245 ; G. Goodson & Sons (Kilburn), £5,564, (a) £1,479 (pool only) ; Payne Bros. (Watford), £5,723 ; George Slade & Co. (Islington), £5,736, (a) £5,853 ; Turner & Payne (Finchley), £5,798 10s. 10d., (a), £5,515 9s. 5d. ; George Bell & Sons, Ltd. (Tottenham), £5,823 11s. 5d., (a) £5,373 ; Frank Parvin, Ltd. (Mill Hill), £5,834, (a) £5,474 ; Holliday & Greenwood, Ltd. (Battersea), £5,950 ; Leonard Lown & Co. (Holloway), £6,030, (a) £5,970 ; T. Watson (Hampstead), £6,031, (a) £5,881 ; A. J. Hill (Hendon), £6,168, (a) £5,858 ; Chessums, Ltd. (Tottenham), £6,297, (a) £5,704 ; Christiani & Nielson (Westminster), £6,320 16s. 7d., (a) £5,550 ; A. Roberts & Co. (Earls' Court), £6,440, (a) £1,750 (pool only); W. Daley & Co. (Acton), £6,539, (a) £6,256 ; John Mowlem & Co. (Westminster), £7,116, (a) £6,746 ; W. Chappell (Maida Vale), £7,726 7s., (a) £7,093 11s. 9d. ; The Borough Engineer's estimate for the work was £5,000.

Hucknall.—The following tenders have been received by the Hucknall Urban District Council for the construction of a 700,000-gallon concrete service reservoir and about 3,370 yards of 10-in. cast-iron mains :—T. Bow (Nottingham), £16,617 ; G. H. Greasley (Leicester), £16,650 ; W. Moss & Sons, Ltd. (Loughborough), £16,700 ; H. Ashley (Mansfield), £17,306 ; J. Dickenson & Co. (Bolton), Ltd. (Bolton), £17,445 ; Evans Bros. (Alfreton), £17,830 ; A. Eastwood & Sons (Warsop),£18,180 ; Netherfield Contracting Co. (Netherfield), £18,341 5s. ; A. Hyslop & Co. (Prestwich), £18,390 7s. ; H. C. Pullar & Co. (Manchester), £18,970 ; Trent Concrete Co. (Netherfield), £18,931 17s. 5d. ; Lane Bros. (Mansfield), £19,077 3s. ; A. L. & H. W. Chown (Northampton), £19,299 4s. ; E. Somerfield & Sons (West Bridgford) £19,565 ; A. H. Price & Co., (Nottingham), £19,593 2s. ; C. S. Tomlinson (Normanton), £19,972 5s. 3d. ; W. Jones & Sons (London), £25,000 ; Johnson & Langley, Ltd. (Leicester), £25,200 ; Bodill & Sons, Ltd. (Hucknall), £25,597 ; Unit Construction Co. (Birmingham), £27,247 ; J. E. Jervis (Long Eaton), £27,500 ; S. Johnson (Hucknall), £28,723 10s. ; G. A. Pillatt & Son (Nottingham), £30,045 ; G. P. Trentham, Ltd. (Hinckley), £30,432 12s. 9d. ; W. J. Sims, Sons & Cooke, Ltd. (Nottingham), £31,191. The tender of Messrs. T. Bow has been accepted.

Leeds.—The Leeds Town Council has accepted the tender of Messrs. William Airey & Son, Ltd., for the completion of 88 houses partly built by the Waller Housing Corporation on the Cross-Gates Estate, at the following prices :—54 houses, £15,800 ; 34 houses, £19,200.

Leeds.—The tender of the Yorkshire Hennebique Co., at £3,298, has been accepted by the Leeds Town Council for the construction of an overhead tank at Moontown.

London.—The London County Council has accepted the tender of Messrs. Walter Lawrence & Son, Ltd., of London, at £678, for the laying of concrete foundations on the Goldsmith's Row (Brady Street area) housing site. Other tenders received were :—C. P. Roberts & Co., Ltd. (Dalston), £730 ; Rowley Bros. (Wood Green), £802 ; J. Carmichael (Contractors), Ltd. (Wandsworth), £806 ; L. H. and R. Roberts (Clapton), £832 ; Patman & Fotheringham, Ltd. (Islington), £986 ; F. and T. Thorne (Isle of Dogs), £1,000 ; Holloway Bros. (London), Ltd. (London), £1,012 ; Holliday & Greenwood, Ltd. (London), £1,029 ; Brand, Pettit & Co. (London), £1,147.

London (Stepney).—The tender of Messrs. J. Jarvis & Sons, Ltd., of 253–255, Hackney Road, E.2, at £390, has been accepted by the Stepney Borough Council for the construction of a concrete floor at the Osborn Street sub-station. Other tenders received were :—W. Harbrow, Ltd., South Bermondsey, £573 ; Holloway Bros. (London), Ltd., Grosvenor Road, S.W.1, £619 ; D. T. Jackson, Barking, £769.

Plymouth.—The Plymouth Corporation has received the following alternative tenders for the erection of houses :—38 houses, Type 168 : In concrete,W. T. Pearce, £1,074 per pair ; in brick—Pearn Bros., £1,108 per pair. 12 houses, Type 170 : In concrete—E. J. Perkins, £2,140 per block of four ; in brick—The Building Guild, Ltd., £2,234 per block of four.

Romford.—The tender of Messrs. T. Muirhead & Co., Ltd., of Westminster, has been accepted by the Romford Rural District Council for the construction of 4,000 yards of 36-inch diameter concrete sewer, and other works, at Dagenham.

Sleaford.—The tender of Messrs. G. Bailey, of Grantham, at £525 6s. has been accepted by the Sleaford Rural District Council for the construction of a reinforced concrete bridge at Digby Fen.

PROSPECTIVE NEW CONCRETE WORK.

Aberdeen.—*Bridge.*—Plans for a new bridge at Corf House, estimated to cost £8,000, have been approved by the Aberdeen Town Council.

Aberdeen.—*Aqueduct.*—The Aberdeen Town Council has decided to construct an aqueduct in connection with the water supply, at a cost of about £53,000.

Aberystwith.—*Sewage Works.*—The Aberystwith Corporation has applied to the Ministry of Health for sanction to a loan of £34,632 for the purpose of a sewage disposal scheme.

Barnsley.—*Road.*—A new road between the Kenesforth and Huddersfield roads is to be constructed by the Barnsley Town Council, at a cost of about £30,000.

Brynmawr.—*Sewage Works.*—The Brynmawr Urban District Council is considering a proposal for the construction of sewage works, at a cost of £28,000.

Bury-St.-Edmunds.—*Open-air Bath.*—The Bury-St.-Edmunds Town Council has decided to construct an open-air swimming bath, at a cost of £2,688.

Chelmsford.—*Road.*—The Chelmsford Urban District Council has decided to approach the Ministry of Transport for financial aid in the construction of an arterial road from Springfield Road to Duke Street, at an estimated cost of £36,000.

Durham.—*Bridge.*—The construction of a bridge across the River Wear at Providence Row, is under the consideration of the Durham Town Council.

Failsworth.—*Road.*—Application has been made by the Failsworth Urban District Council for sanction to a loan of £74,000 for the construction of a portion of a new road between Royton and Manchester.

Halifax.—*Reservoirs.*—The Halifax Corporation is promoting a bill in Parliament providing for the construction of two reservoirs at Heptonstall, at a cost of over half a million pounds.

Huddersfield.—*Open-air Bath.*—Plans for an open-air swimming bath are being prepared by the Huddersfield Borough Architect.

Kidsgrove.—*Sewage Works.*—An inquiry has been held by an inspector of the Ministry of Health into an application of the Kidsgrove Urban District Council for sanction to borrow £28,500 for sewage disposal works.

Leeds.—*Roads.*—The Ministry of Health has sanctioned the borrowing by the Leeds Town Council of £56,022 for the construction of a new road from Elland Avenue to Gelderd Road, and £128,244 for the construction of a new road from Buslingthorpe to Moortown.

Leicester.—*Sewage Works.*—The Ministry of Health has held an inquiry into the application of the Leicester Town Council for permission to a loan of £24,000 for sewage works.

Lewisham.—*Open-air Bath.*—A Ministry of Health inquiry has been held into an application of the Lewisham Borough Council for permission to construct an open-air swimming bath at Bellingham.

Llanelly.—*Roads.*—Two new arterial roads are to be constructed by the Llanelly Town Council at a cost of £20,000.

Lincolnshire.—*Roads.*—The Holland County Council has been recommended by its Roads and Bridges Committee to proceed with the construction of new roads in its area, at a cost of £90,000.

Lowestoft.—*Sea Defence.*—The Lowestoft Town Council has approved the construction of a reinforced concrete sea wall and other works, at a cost of about £5,000.

Lowestoft.—*Sea Defence.*—The Lowestoft Town Council has decided to construct a sea wall between Claremont Pier and Cliff House, at a cost of about £55,000.

Macclesfield.—*Reservoir.*—The Macclesfield Corporation has decided to construct a new reservoir, with a storage capacity of about 500,000 gallons.

Manchester.—*Road.*—The Manchester Corporation has decided to apply to the Ministry of Health for sanction to a loan of £64,500 for the construction of its portion of the arterial road from Royton to Failsworth.

Manchester.—*Roads.*—Considerable new road works are under consideration by the Manchester Corporation. Two new roads in the Gorton and Parr's Wood districts have received Government approval, and an arterial road, 100 ft. wide, between Royton and Failsworth is being considered by the Town-Planning Committee.

Millom.—*Reservoir.*—The Millom Urban District Council is considering a water supply scheme, which includes the construction of a reservoir, prepared by Mr. Beswick, A.M.Inst.C.E., of Whitehaven. The estimated cost of the work is £12,000.

Northam.—*Reservoir Works.*—Application is to be made to the Ministry of Health by the Northam Urban District Council for permission to increase the capacity of its reservoir at Melbury.

Oxenhope.—*Reservoir.*—The Oxenhope Urban District Council has received permission to borrow £17,000 for the construction of a reservoir.

Peterborough.—*Sewage Works.*—A Ministry of Health inquiry has been held into an application of the Peterborough Corporation for permission to borrow £9,190 for sewage disposal works.

Poole.—*Houses.*—The Poole Town Council has applied to the Ministry of Health for permission to borrow £34,042 for the purpose of completing the concrete houses which it has already partly erected.

Portsmouth.—*Docks.*—The Corporation of Portsmouth has under consideration an extensive scheme of improvements at the docks and harbour.

Radstock.—*Road.*—A new road between Radstock and Midsomer Norton is to be constructed by the Radstock Urban District Council.

Ramsgate.—*Waterworks.*—The Corporation of Ramsgate is considering the construction of new waterworks at Minster, at a cost of about £30,000.

Rotherham.—*Sewage Works.*—A scheme for the construction of new sewage works at Maltby, at a cost of £24,000, has been approved by the Rotherham Corporation.

Scunthorpe.—*Waterworks.*—The Ministry of Health has held an inquiry into the application of the Scunthorpe and Frodingham Urban District Council for sanction to borrow £52,000 for extensions at the waterworks.

St. Austell.—*Sewage Works.*—Application has been made to the Ministry of Health by the St. Austell Rural District Council for permission to borrow £4,000 for a sewage disposal scheme.

ST. JUST (CORNWALL).—*Reservoir.*—The Urban District Council of St. Just has decided to apply for sanction for the construction of a reservoir at Carn Bosavern.

STOKE-ON-TRENT.—*Sewage Works.*—The Ministry of Health has approved of the carrying out of sewage works by the Stoke-on-Trent Town Council, at an aggregate cost of nearly £100,000.

STROUD.—*Reservoir.*—The Stroud Urban District Council has decided to construct a new storage reservoir in connection with its water supply.

TETBURY.—*Reservoir.*—The Tetbury Urban District Council is considering a scheme for the construction of a reservoir, with a capacity of half a million gallons of water.

WELSHPOOL.—*Water Supply.*—The Welshpool Town Council is considering a scheme for the improvement, at a cost of about £20,000. The scheme includes the construction of a dam at the reservoir.

WHITEHAVEN.—*Waterworks.*—The Whitehaven Rural District Council has decided to apply to the Ministry of Health for sanction to a loan of £45,000 for the supply of water to various parishes.

WHITLEY.—*Sea Defence.*—Plans for the construction of a sea wall, at an estimated cost of £25,000, have been approved by the Whitley and Monkseaton Urban District Council.

WORCESTER.—*Reservoir.*—The question of applying for sanction to borrow £50,000 for the construction of two new reservoirs is under consideration by the Worcester Corporation.

NEW COMPANIES REGISTERED.

R. HINDMARCH, LTD. (178,399). Registered December 14, 1921. 42, Osborne Avenue, South Shields. Plasterers and cement manufacturers, etc. Nominal capital, £500 in 500 £1 shares. Directors: J. R. Brown, 13, Grange Avenue, South Shields, and R. Hindmarch, 2, Albany Street, South Shields. Qualification of directors, one share; remuneration to be voted.

S. DAVEY & CO., LTD. (178,799). Registered January 2. 4, Pavilion Buildings, Brighton. Manufacturers of concrete products. Nominal capital, £3,500 in 3,500 £1 shares. Directors: F. W. Wilson, 12, Windlesham Gardens, Brighton; J. Marwick, 31, Sackville Road, Hove; S. Davey, 4 Compton Avenue, Brighton; and G. A. Golding, Haywards Heath. Qualification of directors, £100; remuneration, to be voted by Company.

E. GODLEY, LTD. (178,842). Registered January 4. 29, Knowles Street, Accrington. Manufacturers, dealers and workers in cement, etc. Nominal capital, £4,500 in 4,500 £1 shares. Directors; E Godley, G. Godley, and F. Godley, all of Knowles Street. Qualification of directors, 250 shares; remuneration, to be voted by Company.

RECENT PATENT APPLICATIONS.

142,487.—H. Bassmann: Manufacture of resistant porous concrete pipes.
147,646.—A. C. Pohlmann and P. A. R. Frank: Concrete wall.
151,604.—F. A. Palen: Building construction.
170,456.—H. P. Amphlett and the Hume Pipe & Concrete Co., Ltd.: Reinforcement for concrete.
170,497.—N. P. Nielsen: Manufacture and treatment of cement goods.
170,541.—W. P. Hayes and P. G. Hayes: Concrete construction.
170,611.—G. C. Thomas: Machine for the manufacture of artificial stone.
170,693.—N. and S. Cohen: Device for use in moulding buildings in sand.
170,741.—H. Addison: Slab and wall construction.
170,884.—A. J. Francois: Reinforced concrete linings for mineshafts, tunnels, etc.
170,903.—F. S. Sumpter and R. F. F. Hamlett: Concrete block and slab-making machines.
170,912.—A Francois: Cementation.
170,966.—E. V. Gabriel: Building slabs or beams.
170,985.—F. M. Sawyer: Wall construction.
171,042.—J. C. Gledhill and A. E. Gledhill: Reinforced concrete portable coppers.
171,082.—L. Freeborn.—Reinforced concrete columns.
171,172.—D. E. Williams: Dry docks, locks, and similar structures.
171,211.—J. Fowler & Co. (Leeds), Ltd.: Earth excavators.
171,225.—F. H. Heaven: Hollow concrete wall construction.
171,417.—J. Forster and P. McLachlan: Construction of slab buildings.
171,529.—W. H. Stevens: Concrete buildings.
171,541.—H. Wagner: Wall construction.
171,624.—L. S. A. Cullen: Concrete building blocks and concrete construction.
172,040.—Concrete Dwellings, Ltd., and P. Gray: Method of casting *in situ* concrete walls.
172,164.—J. S. Baines and T. H. Joyce: Building blocks.
172,354.—D. J. Owen: Concrete block-making machines.
172,475.—B. O. W. Hesselman and O. M. G. Mattison: Hollow block-making machine.
172,585.—N. Vaux: Tiles for concrete construction.

PUBLISHER'S NOTICES.

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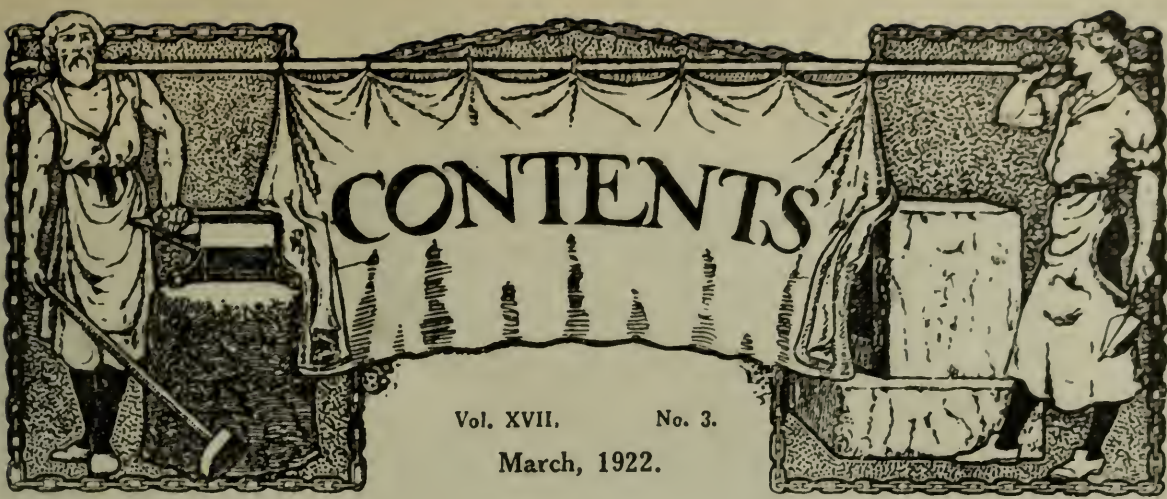
COAST PRESERVATION IN BRITISH GUIANA—WALL AT LUSIGNAN, EAST COAST, SHOWING FOUR LINES OF SEA DEFENCES WHICH HAD TO BE SUCCESSIVELY ABANDONED.

(*For description see page 157.*)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ECONOMISE !
by having RANSOME the *quality* plant—it may cost a little more, but remember RANSOME
CONCRETE MIXERS
CONCRETE-PLACING PLANT
STEEL PILING PLANT
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CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 3. LONDON, MARCH, 1922.

EDITORIAL NOTES.

SIR CHARLES RUTHEN, COLLABORATION, AND HOUSING.

THE event of Sir Charles Ruthen's recent utterances is now sufficiently remote to enable us to consider them with that purged and dispassionate view so essential for a just assessment. Amongst a mass of strongly worded invective against the architectural profession emerges this main accusation: that architects are more concerned with their dignity and the preservation of a somewhat effete etiquette, than with immediate and contemporary national affairs. They are, in fact, out of touch with contemporary aspirations, conditions and thought. They live upon the past and ignore the present. " One wondered whether the architect of this enlightened century had really grasped his full responsibilities, and whether he had the slightest appreciation of the great part planned out for him and his art in modern civilisation." These are strong words, but, for our own part, we feel that they are not uttered without some justification; indeed, our feelings in this matter, as it affects the concrete industry, have been expressed in these columns from time to time when we have deplored the fact that the greater part of the profession persistently ignores the architectural possibilities of concrete, whilst other countries are busy with its successful exploitation. We have also pointed out that in our opinion it is compatible with the maintenance of professional dignity to keep in touch with the constantly changing conditions of the age, a manifestation of which is the emphatic need for close co-operation between the architect and the technical expert. That this necessity is still not appreciated by many members of the profession, is seen by the publication of a letter and circular in a recent number of the *Journal of the Royal Institute of British Architects.*

In this letter the Secretary of the Institute takes exception to a circular sent out to architects by a firm of constructional engineers specialising in reinforced concrete, who write to enquire if the recipient will undertake the " architectural treatment " of various structures with the execution of which the firm has been entrusted. A request is made, at the same time, for a statement as to the scale of fees required for carrying out work on these lines. The circular letter then proceeds to point out that " on the basis of mutual co-operation " the firm expect to have the opportunity of submitting a free design for the structural part of any suitable building that the architect may have on hand. To this document the Practice Standing Committee of the R.I.B.A. has taken exception, stating that it " is a proposal which no reputable architect would consider for a moment, it being entirely contrary to the code of professional conduct which members of this Institute make it a point of honour to observe."

By a curious coincidence the publication of these letters occurred soon after the address of Sir Charles Ruthen, and they would seem to constitute a certain justification for some of the charges of aloofness and sedate isolation from the tendencies of the day, which the architectural profession insists upon maintaining. This attitude is rendered all the more lamentable owing to the fact that there exists, just now, without doubt, a shortage of work in the ranks of the profession, whose members are the first to deplore ugliness and lack of composition in engineering structures.

To us the proposal would seem to contain nothing to which an honourable man could take exception. The architect, who may be employed by a firm of constructional engineers as collaborator with them in the design of some structure is asked, in return, and when the occasion arises, to give the engineering firm an opportunity to tender for the structural work on any suitable building that the architect may have on hand. Presuming that the constructional firm is a reputable one, and if it were not the co-operation should not be entered into in the first place, it appears to us that common decency would be sufficient to suggest the course indicated in the letter.

Sir Charles' remarks, however, were chiefly directed against the professional attitude with regard to housing. Despite certain notable exceptions, there was a failure on the part of architects to co-operate *to the utmost of their capacity* with the Government in its housing endeavours: a failure to grasp the fact that the new conditions demanded new treatment, and that professional pride must give way before the relentless mutability of conditions. An aspect of this failure is seen in connection with concrete cottage work, the advancement of which has mostly been in the hands of those outside the ranks of a profession which obdurately refused to handle a new material, although it offered a partial solution to the pressing problem of providing less costly houses.

Unless a rapid change of front takes place, a similar difficulty is about to arise again. Houses for the middle and working classes must be provided, and although the activities of the speculative builder have been treated with obloquy, it is through their repetition that the houseless now seek alleviation. But the speculative builder makes no claim either to an artistic temperament or education; if, however, the architect, who is presumed to have benefitted by both, will overcome his pride and enter into the arena of practical affairs, he may find here by collaboration a means of benefitting both himself and his country. We know of more than one pre-war example of such a collaboration between a well-known architect and a speculative builder which amply justifies our desire for its extension.

There is no doubt that the architect has some quite definite and special contribution to make to the community, but he must be prepared to market his wares both at a price and in a manner that meet the requirements of the day. There is, after all, nothing immutable in the present commission basis for architectural services. The reason that the countryside and the purlieus of all our towns are disfigured to-day in a manner that all of us—architects, most of all—deplore is because the architect has in the past been willing to work only upon his own terms, and to these the speculative builder has, often with reluctance, been unable to agree. In the past, however, there has been enough work of a different kind to occupy the architectural profession, for the most part, so that by this refusal to lend his aid to the essential, but humbler kind of work, it is the nation that has been the chief sufferer. The advent of the war, however, has had the effect of hastening an economic and social change, resulting in the almost entire elimination of one important class of building ; that of the large house. So that the work of the present and the future lies more and more in the erection of small houses, and it is a work which architects should do all in their power —both for their own and their country's good—to assist, and if their present code of professional etiquette and scale of fees hinder their whole-hearted entry into this work, then it is surely time that some adjustment was made. This is the interpretation that we set to the somewhat vitriolic utterances of Sir Charles Ruthen.

COLLAPSE OF THEATRE ROOF AT WASHINGTON.

The collapse of the roof of the Knickerbocker Theatre, which in turn involved the balcony, and resulted in 95 deaths and 200 injuries, has naturally aroused considerable comment in the non-technical press, and, as usual, those who know least have been most ready to supply full explanations and advice.

We have already heard from different sources that it was due to the action of frost on a concrete roof, to neglect of provision against expansion and contraction, to neglect of proper provision against snow load, etc., etc.

At the date of writing, the available information is not sufficient to base any definite conclusions on, and, in fact, so far the explanation is rather baffling.

The collapse occurred on January 27, and the theatre had been completed for four years. It is therefore unlikely that frost in concrete during construction had anything to do with it, even if it occurred.

The roof apparently consisted of steel trusses resting partly on steel columns and partly on the walls, which, judging from photographs, acted as retaining walls to the streets, the theatre being sunk considerably below street level.

So far, what evidence there is goes to show that a proper snow allowance (much more than the actual weight of snow) had been made, and that ordinary stress limitations had been complied with.

Apparently the trusses merely rested on joists in the wall without being bolted to them, and as the evidence of eye-witnesses seems to show that the end of the main truss supported on the wall fell bodily, it appears probable that sliding of the truss on its bearing had occurred and it had become unseated. Possibly creep due to expansion and contraction would contribute to this, coupled, perhaps, with a final shortening of the main truss in the exceptional snow-storm.

At present we must patiently await further information, but at any rate the people who have already associated the failure as having some connection with reinforced concrete would do well to keep silent, as so far the reinforced concrete appears to be the most innocent portion of the structure.

The information herein is obtained from the instructive article in *Engineering News Record* of February 2.

ROAD DEVELOPMENT.

The necessity of providing work for the unemployed during the past two winters has considerably disorganised the normal programme of outdoor work by local authorities, and much work which, under ordinary conditions, would not have been put in hand until the spring, has been proceeded with throughout the bad weather. Although this work has alleviated a great deal of distress, owing to the frequent stoppages due to inclement weather it cannot, of course, give as good a return for money spent as similar operations carried out during the spring and summer. Now the better weather is within measurable distance, however, local authorities will undoubtedly be considering still further activities in this direction. The largest item in the unemployment relief schemes (as in municipal work in more normal times) is road construction and reconstruction, and rightly so; for the increasing use of motor transport is emphasising more every day the important position the roads will take in the trade and commerce of the country in the future. Motor manufacturers are using every endeavour to regain for the roads the popularity they once enjoyed, and the penetration of heavy char-à-bancs and lorries to rural districts has presented to local authorities a problem which will have to be solved. The advent of the motor omnibus led to the reconstruction on more solid lines of the roads which they used, and it is obvious that those responsible for the maintenance of second- and third-class roads in rural areas will have to follow in the same direction. Motor transport has come to stay, and it is essential for the well-being of the country that a network of roads should be formed to accommodate this class of traffic. Many of the existing roads are entirely unsuited for heavy or fast traffic, and their widening and reconstruction will involve immense expense. But it is a position which has to be faced, and we are convinced that it would be false economy to rebuild these roads on any but the best system known to modern science. In such matters the initial outlay is not the chief consideration and, although it might be more costly in the first place, the concrete road, by reason of the length of its life and low upkeep costs, is worthy of very serious consideration.

CONCRETING IN COLD WEATHER.

In drawing the attention of our readers to the results given in this issue of some experiments on the effect of the heat generated in concrete whilst it is setting in checking the effects of frost, we would emphasise the necessity of taking every precaution for the protection of work in progress at this time of the year. Providing adequate methods are adopted for heating the materials and covering the work so soon as it is laid, there is no reason (except, perhaps, extra cost) why concrete construction should not proceed during the most severe weather. In winter, frosts are expected and prepared for, but the bright spring days are very liable to engender carelessness. It has to be remembered, however, that at this time of the year, warm, sunny days are often followed by sharp frosts during the night, which play havoc with work not properly protected. The motto should be "Prevention is better than cure"—a little trouble in covering up is much easier and less expensive than cutting away and making good.

PLAISANCE KOKER. LAND SIDE.

COAST PRESERVATION IN BRITISH GUIANA.

By HERBERT L. VAHEY.

INTRODUCTORY.

THE notable achievement described in the following pages is remarkable in two respects : It is the largest work of its kind in the world—involving a total expenditure of over £1,000,000—and it represents the solution of an exceedingly intricate problem in coastal protection, which, since 1750 when the colony was in the hands of the Dutch, has defied engineering skill effectively supported by lay ingenuity.

Early in 1916 the Commission sitting to consider the acute question of immediate " sea-defence " decided to discontinue former methods, and to obtain expert advice. Shortly afterwards Mr. Gerald Otley Case, A.M.E.I.C., Assoc.M.Am.Soc.C.E., M.S.E., was called in to report upon the matter. As a result of his investigations and recommendations he was appointed Consulting Engineer to the Government of British Guiana, and instructed to prepare, and subsequently supervise, the scheme which is the subject of our articles.

EARLY METHODS OF PROTECTION.

Although British Guiana can hardly be said to obtrude itself either upon the man in the street or the keen student of Empire geography, it is a colony of considerable importance, being rather larger than Great Britain. Not being an island, however, its coast line cannot compare with that of the Mother Country, being, indeed, no more than 135 miles in length. Nevertheless the health and wealth of British Guiana are entirely dependent upon the solidarity and soundness of her shores. This is due to the fact that practically all the land abutting on the sea is from 2 to 4 ft. below high water level ; even Georgetown, the capital, and the principal sugar estates, are several feet below water level at high tide.

The question of permanent and impregnable coastal protection was, therefore, one of supreme importance, and of recent years it has become a matter of extreme urgency, owing to the accelerated rate of erosion, and the consequent deluging of cropped lands and estates.

Some idea of the seriousness of the position may be gained from a perusal of the following records : From 1792 to 1874 the average rate of erosion was 10·57 ft. per annum,* from 1874 to 1890 it was 79·00 ft. per annum, and between 1890 and 1916 it was 23·80 ft. per annum ; while during the corresponding periods the accretions were almost negligible.

Each year, though every endeavour was made to check the steady encroachment of the sea, saw a further retirement before the invader ; landmarks and boundaries had to be removed further and further from the coast, and in not a few cases valuable estates had to be completely abandoned.

Enormous sums were expended in unsuccessful attempts to combat the regular advance of the sea ; indeed, shortly before the present work was put in hand the amount expended annually upon the maintenance of the coastline exceeded £55,000. Unfortunately, most of this sum was spent on the erection

Fig. 1. Sea Wall on East Coast showing Abandoned Wooden Protective Works.

of bulkheads, vertical sheet piling, wave screens, improperly constructed and uselessly situated groynes, wood fascines, earth dams, etc., and the result, as is clearly demonstrated in the Frontispiece, has been disastrous. In *Fig.* 1 no fewer than four separate and distinct " lines of defence " may be traced, each having been successively abandoned as soon as its inadequacy was perceived. And this is not an isolated instance. All along the coast a similar state of things existed previous to 1916—the whole panorama presenting a sorry history of costly failure, and a dismal picture of sea-conquered territory.

The lack of success which attended all former endeavours, though deplorable, was in no sense a reflection upon those who undertook the work ; they, indeed, were in no small degree the victims of circumstance. It could scarcely be expected that a Director of Public Works—whose duties in such a colony are multifarious—could with reasonable prospect of success tackle a problem which taxes the skill, experience, and ingenuity of the expert and the specialist to the utmost.

* The low average of this period was due to the formation of the Lusignan Spit, a natural barrier having a maximum width of 6,000 ft., which subsequently disappeared.

Moreover each successive official acting in this capacity had neither sufficient reliable data nor adequate funds to deal with the matter basically. They had, therefore, to content themselves with schemes dealing with effects rather than causes.

It was not until 1915, when numerous and extensive sea encroachments involving the abandonment of many large plantations and estates revealed the seriousness of the position, that the Governor, Sir Walter Egerton, K.C.M.G., appointed a special commission to consider the whole question of coast protection. In fairness to those in authority, previous to the date given, it should be pointed out that the danger in which the colony stood had not gone unperceived, and many and vigorous appeals were put forward advocating immediate and purposeful action. Previous to the appointment of the Hon. E. C. Buck, the present

Fig. 2. Showing Scour behind Vertical Piling.

Director of Public Works, those in charge of this department had repeatedly drawn attention to the perilous position, and the insufficiency of the existing "sea-defences"; while he himself has forcefully urged the instant adoption of a policy based upon more scientific methods.

Another factor militating seriously against the success of this enterprise was the lack of co-ordination; work was done piecemeal, and even then was not properly maintained. The problem, too, was further complicated by the ill-considered action of those occupying estates adjoining the shore; each owner being anxious to obtain security for his own acres took steps to divert the destructive action of the sea to his neighbour, with the result that the whole foreshore became irregular, and the condition which all were anxious to abate was aggravated.

In short, the continuance of coast erosion was due to the lack of a firm policy, backed by special knowledge of the subject. Few engineers who have not specialised are aware of the existence, or nature, or operation of innumerable destructive forces which by their incessant action ultimately lead to the obliteration of littoral boundaries, and the inundation of hundreds of thousands of low-lying acres.

Few engineers who have not made coast erosion a special study realise

Fig. 3. Showing Scour behind Sheet Piling.

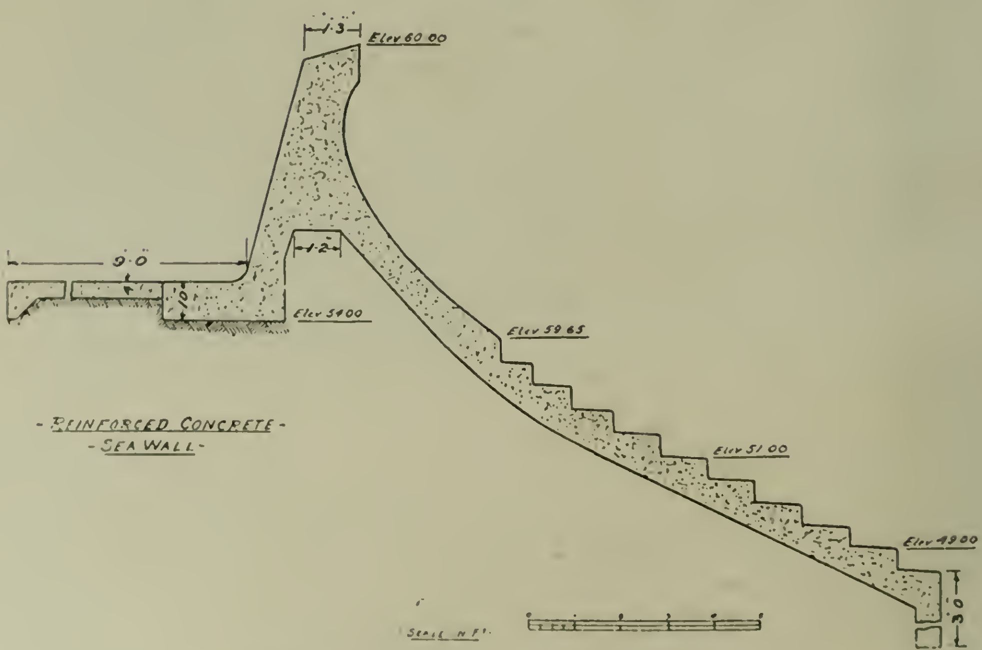


Fig. 4. Reinforced Concrete Sea Wall.

the enormous part played in shore alteration by waves, wind-formed currents, tidal currents, currents caused by estuaries, rivers, and drainage outlets, and by wind action; few, also, realise the tremendous influence which dead trees, the destruction of vegetation, the removal of sand, gravel, or shell, rain, changes in the sea-bed, the use of vertical sheet piling, wave screens, high groynes, stone-filled groynes, or other incidental or artificial obstructions to littoral drift, have in shaping sea-boundaries.

It is not strange, therefore, that all previous efforts—which were put forth without full and proper knowledge of the controlling conditions—were foredoomed.

THE PRESENT SCHEME.

The consulting engineer responsible for the design and supervision of the present scheme had, therefore, to begin, as it were, at the beginning, and institute careful and detailed investigations into the origin and causes of the condition in

FIG. 5. SECTION OF SEA WALL AT LUSIGNAN.

FIG. 6. EARTH WALL AT TRIUMPH. EAST COAST.

which he found the coast. This meant extensive and tedious research covering a very wide range of subjects indirectly connected with the problem, and a close personal scrutiny of the conformation, outline, and geographical features of the entire foreshore.

As he anticipated from cursory observation, Mr. Case discovered that, to a very large extent, the actual damage caused, and the unsatisfactory state of the coast generally, was due to the manner in which the sea-defences had been designed, and also to their actual location. A glance at *Figs*. 2 and 3 will show

how entirely inadequate were the methods adopted prior to 1916. As will be seen, barriers of this description merely tend to aggravate the original trouble by providing a position about which the scouring action of the sea could concentrate itself. This, in point of fact, is what happened. Behind every range of sheet piling, and on the leeward of groynes, fascines, etc., large hollows were formed which in time completely undermined the structure, and merely intensified the difficulties to be overcome.

It was, therefore, decided that all previous attempts should be ignored—from the point of view of their utility—and that a more scientific system should be adopted. As a result Mr. Case prepared the scheme which is the subject of these articles.

As the matter was extremely urgent—so urgent, indeed, that both the British and American Governments readily granted special priority permits for materials to be shipped during the most critical period of the war—Mr. Case decided to proceed at once with the permanent protection of some 52¼ miles of coast on which the occurrence of serious and extensive damage was, if not imminent, at least distinctly possible.

This involved the provision of:

111 specially designed, low, reinforced concrete groynes. Some being 750 ft. long, spaced at 1,500 ft. apart; others being 500 ft. long, and spaced at 1,000 ft. apart.

25,400 lin. ft. of reinforced concrete sea walls.

24,400 lin. ft. of reinforced concrete sluice runs, and sluices.

46,000 lin. ft. of earth dams.

28,950 lin. ft. of public road diverted to accommodate the scheme,

the estimated total of the whole being 1,753,100 cub. ft. of reinforced concrete; to which should be added a large quantity of concrete and cement used, as it were, incidentally.

The total cubic content of the wood used to form groynes, fascines, sheet-piling, wave screens, etc., could not be computed, as more than half of the material used even in the most recent protective scheme had been destroyed and carried away by the action of the sea.

The system selected to deal with the special and intricate problems which presented themselves for instant solution was that devised by Mr. Case's father (the late Edward Case, A.M.I.C.E., F.R.G.S., formerly of the Public Works, Ceylon), and the scheme herein referred to was carried out in strict accordance with the principles laid down by Mr. Case, senr., i.e. the low groyne, set at a special angle relative to the littoral boundary coupled with the employment of a curved sea wall, having a varying elliptical section, rising, as it were, from a stepped foundation. Since the design of these features is almost entirely dependent upon local conditions, it is difficult to furnish a section which may be regarded as representative or characteristic. Nevertheless, *Fig.* 5, taken in conjunction with the other illustrations, will give a fair idea of the typical curvature.

The basic idea underlying the system adopted is to use, and not to oppose, the forces of the sea, so that in various ways the foreshore may be built up in a "natural" angle over which the waves may roll harmlessly, expending their energy before reaching the high-water mark.

In detail Mr. Case's investigations led him to the conclusion that, with the materials available, and under the adverse circumstances then obtaining, nothing less than the following could be regarded as protective work calculated to produce an efficient safeguard to the steady encroachment of the sea, and in his report to

Fig. 7. New Sea Wall. East Coast.

Fig. 8. Reinforced Concrete Faced Dam. (10 Steps.)

the British Guiana Government he strongly advised that the items enumerated below should be proceeded with without delay :—

1. Where possible, to straighten the line of protecting dams by abandoning the existing outer protecting dams, and building new dams further inland.

2. Reinforced concrete sea walls, in place of earth ones, should be built on the most exposed parts of the coast. (See *Figs*. 6 and 7.)

3. Where the earth dams were liable to be attacked by wave action to face them with reinforced concrete. (See *Fig*. 8)

4. Construct new reinforced concrete drainage sluices in line with the sea wall or concrete-faced earth dam. (See *Fig*. 9 and illustration at head of this article.)

5. Construct training walls or groynes on each side of the drainage outlet to guide the water direct to sea.

6. Construct a system of low groynes in front of all exposed sea walls.

7. Remove all existing structures, such as wave screens, high groynes, and vertical sheet piling, which were causing erosion.

8. Encourage the growth of suitable vegetation in front of the dams.

9. Prohibit the removal of shell from the front of sea dams.

10. Prohibit the destruction of any useful vegetation.

In the concluding article, which will appear in our issue of April, the author will describe the progress of the work, the difficulties to be overcome and the remarkable success which has attended the whole enterprise, which, as has been pointed out, is the largest of its kind in the world.

Fig. 9. Lusignan Koker (Sluice). End View.

THE CONCRETE INSTITUTE.

MONTHLY NOTES.

By the SECRETARY.

CONFERENCE AT THE BUILDING EXHIBITION, 1922.

By the courtesy and kindness of Mr. H. Greville Montgomery (Director of the Exhibition), the Concrete Institute is holding a series of conferences at the Building Exhibition at Olympia, on Topics of the Moment.

The Conference will be opened each day by a short paper, copies of which will be obtainable in advance from the Secretary of the Institute; and an open discussion will follow each paper.

The following syllabus has been arranged :—

Date.	Subject.	Opened by	Time.
Tues., April 18.	(*a*) Training the Concretor.	The President.	5.30 p.m.
	(*b*) Recent developments in the Industry.	,, ,,	
Wed., April 19.	(*a*) Concrete Roads.	Dr. O. Faber, O.B.E.	,,
	(*b*) Use of reinforced concrete in highway bridges.	,, ,,	
Thurs., April 20.	" What life can be assigned to works of reinforced concrete for the purpose of Government loans ? "	Mr. G. C. Workman.	,,
Fri., April 21.	(*a*) Concrete block building.	Mr. E. S. Andrews, B.Sc.	,,
	(*b*) Reinforced floors.	,, ,,	
	(*c*) Use of pre-cast work in building structures.	,, ,,	

Further information may be obtained from the Secretary of the Concrete Institute, 296, Vauxhall Bridge Road, S.W.1.

MEETING IN MARCH.

The 110th Ordinary General Meeting will be held at the Headquarters of the Institute, 296, Vauxhall Bridge Road, S.W.1, on Thursday, March 23rd, 1922, at 7.30 p.m., when a paper (illustrated with lantern slides) will be read by Mr. S. F. Staples, M.Inst.C.E., M.I.N.A., on " Floating Docks."

Members may obtain tickets for their friends on application to the Secretary.

THE ANNUAL DINNER.

Some 250 members and guests assembled for the Annual Dinner, held at the Savoy Hotel on February 2nd. Amongst the guests were H.M. Minister of Health, the Rt. Hon. Sir Alfred Mond, Bart., M.P.; the Rt. Hon. Lord and Lady Riddell; the Very Rev. Dean Inge; Sir Alfred and Lady Robbins; and very many other distinguished ladies and gentlemen.

A very successful evening was enjoyed, and a full report will appear in the *Journal* in due course.

CONCRETE AGGREGATES.—(*continued*).

Merionethshire—North.

(1) *General description :* Local granite.
(2) *Source and locality of same :* Festiniog Quarry.
(3) *How obtained :* Quarrying and Crushing.
(4) *From whom obtained :* Festiniog Granite Co.
(5) *Is available quantity limited ? If so, how ?* Only output limited.
(6) *Present maximum output per day (stated in cubic yards) :* Not working at present for lack of demand.
(7) *Transport facilities :* Festiniog Railway.
(8) *Is there any provision at or near source for washing or crushing ?* Yes.
(9) *Is composition uniform ?* Yes.
(10) *Detailed description :—*

(*a*) *Kind of stone or coarse material :* Granite.
(*b*) *Kind of sand or fine material :* Siftings from same.
(*c*) *Relative proportions of coarse and fine material :* 4 to 1.
(*d*) *Shape of particles (rounded, angular, flat, etc.) :* Angular.
(*e*) *Size of particles ; approximate percentage that needs crushing to pass ¾ in. screen ;* Various, all require crushing.
(*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* None.

(11) *Is sample sent with this sheet ?* No.
(12) *General remarks :* Excellent material, but Quarry not working at present.

Merionethshire—N.E. District.

(1) *General description :* Local granite.
(2) *Source and locality of same :* Wernddu Quarry.
(3) *How obtained :* Quarrying and crushing.
(4) *From whom obtained :* Dee Clwyd Granite Quarries Co., Ltd.
(5) *Is available quantity limited ? If so, how ?* Only output limited.
(6) *Present maximum output per day (stated in cubic yards) :* About 50.
(7) *Transport facilities :* London North Western Railway, direct connection.
(8) *Is there any provision at or near source for washing or crushing ?* Yes.
(9) *Price per cubic yard, and where delivered :* 8*s.* 6*d.* in trucks at Quarry.
(10) *Is composition uniform ?* Yes.
(11) *Detailed description :—*

(*a*) *Kind of stone or coarse material :* Granite as above.
(*b*) *Kind of sand or fine material :* Siftings from same.
(*c*) *Relative proportions of coarse and fine material :* 4 to 1.
(*d*) *Shape of particles (rounded, angular, flat, etc.) :* Angular.
(*e*) *Size of particles ; approximate percentage that needs crushing to pass ¾ in. screen :* Various, all require crushing.
(*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* None.

(12) *Is sample sent with this sheet ?* No.
(13) *General remarks :* Excellent aggregate.

Merionethshire—Central.

(1) *General description :* Local granite largely basalt.
(2) *Source and locality of same :* Arenig Quarry.
(3) *How obtained :* Quarrying and crushing.
(4) *From whom obtained :* Arenig Granite Co., Ltd.
(5) *Is available quantity limited ? If so, how ?* Only output limited.
(6) *Present maximum output per day (stated in cubic yards) :* About 50.
(7) *Transport facilities :* Great Western Railway direct connection.
(8) *Is there any provision at or near source for washing or crushing ?* Yes.
(9) *Price per cubic yard, and where delivered :* 8*s.* 6*d.* in trucks at Quarry.
(10) *Is composition uniform :* Yes.

(11) *Detailed description :—*

- (*a*) *Kind of stone or coarse material :* All granite as above.
- (*b*) *Kind of sand or fine material :* Siftings from above.
- (*c*) *Relative proportions of coarse and fine material :* 3 to 1.
- (*d*) *Shape of particles (rounded, angular, flat, etc.) :* Angular.
- (*e*) *Size of particles ; approximate percentage that needs crushing to pass ¾ in. screen :* Various, all require crushing.
- (*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* None.

(12) *Is sample sent with this sheet ?* No.
(13) *General remarks :* Excellent aggregate.

Merionethshire—S.W.

(1) *General description :* Local granite Syenitic nature.
(2) *Source and locality of same :* Tonfanan Quarry.
(3) *How obtained :* Quarrying and crushing.
(4) *From whom obtained :* Tonfanan Quarry Co., Ltd.
(5) *Is available quantity limited ? If so, how ?* Only output limited.
(6) *Present maximum output per day (stated in cubic yards) :* About 30.
(7) *Transport facilities :* Cambrian Railway, direct connection.
(8) *Is there any provision at or near source for washing or crushing ?* Yes.
(9) *Price per cubic yard, and where delivered :* 9*s.* in trucks at Quarry.
(10) *Is composition uniform ?* Yes.
(11) *Detailed description :—*

- (*a*) *Kind of stone or coarse material :* All granite as above.
- (*b*) *Kind of sand or fine material :* Siftings from above.
- (*c*) *Relative proportions of coarse and fine material :* 4 to 1.
- (*d*) *Shape of particles (rounded, angular, flat, etc.) :* Angular.
- (*e*) *Size of particles ; approximate percentage that needs crushing to pass ¾ in. screen :* Various, all require crushing.
- (*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* None.

(12) *Is sample sent with this sheet ?* No.
(13) *General remarks :* Excellent aggregate.

Merionethshire—N.W. District.

(1) *General description :* Local granite Syenitic nature.
(2) *Source and locality of same :* Minffadd Quarry.
(3) *How obtained :* Quarrying and crushing.
(4) *From whom obtained :* Pwllheli Granite Co., Ltd.
(5) *Is available quantity limited ? If so, how ?* Only output.
(6) *Present maximum output per day (stated in cubic yards) :* About 50.
(7) *Transport facilities :* Cambrian Railway direct connection.
(8) *Is there any provision at or near source for washing or crushing ?* Yes.
(9) *Price per cubic yard, and where delivered :* 8*s.* 6*d.* in trucks at Quarry.
(10) *Is composition uniform ?* Yes.
(11) *Detailed description :—*

- (*a*) *Kind of stone or coarse material :* All granite as above.
- (*b*) *Kind of sand or fine material :* Siftings from.
- (*c*) *Relative proportions of coarse and fine material :* 4 to 1.
- (*d*) *Shape of particles (rounded, angular, flat, etc.)*—Angular.
- (*e*) *Size of particles ; approximate percentage that needs crushing to pass ¾ in screen :* Various, all require crushing.
- (*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* None.

(12) *Is sample sent with this sheet ?* No.
(13) *General remarks :* An excellent aggregate.

THE EFFECT OF HUMIDITY, TEMPERATURE AND WATER CONTENT ON THE STRENGTH OF CONCRETE.

By ERNEST JOHN HAMLIN, D.Sc., A.M.Inst.C.E., etc.

[*Abstract from a paper read before the Concrete Institute on December 15th.* 1921.]

Introduction.

The author has divided the following paper into two portions. The preliminary work was finished by him in 1917 and is marked "Preliminary Researches." When the author returned to South Africa in 1919, he was fortunate to travel with Mr. W. J. Cooper, Managing Director to the Penarth Cement Works, who brought several facts to his attention. Mr. Cooper discussed the use of concrete mixers with the author, and suggested that the water content was an important branch of research in South Africa. Over 3,000 specimens have been tested and these results are marked "Further Researches."

Preliminary Researches.

Concrete is now being used extensively in many classes of constructional work, but in South Africa the atmospheric conditions are entirely different for different parts. A few miles distance often means a difference in altitude of 2,000 or 3,000 ft., etc. The author, feeling that these different weather conditions must have some direct bearing on the strength of concrete, has investigated, in a limited degree, how the strength varies under different temperatures, and in dry and humid atmospheres. This knowledge is of economic importance because the contractor—or engineer—must know when to remove his shuttering, etc.

The greatest difficulty was experienced to represent with any degree of accuracy atmospheric conditions; this was overcome by the use of an excellent design of electrical thermostat.

Materials Used.

The following gives a brief outline of the class of material used throughout the experiments.

Sand.—Sand was taken from the Plankenberg River in the Division of Stellenbosch, South Africa. It was very thoroughly washed and then spread upon trays and sun-dried. Its specific gravity was approximately 2·70 with an average density 1·782 in C.G.T. units. The average percentage of voids was 34.

Stone.—The stone used was Paarl Granite. It was a fairly uniform sample and after being carefully washed was such that it would pass through a ½-in. screen, but not through a ¼-in. screen. Its specific gravity was 2·87 with an average density of 1·466. The average percentage of voids was approximately 48.

Cement.—Pretoria Portland cement was used throughout; the usual tests of the British Engineering Standards Committee as regards fineness and tensils were taken for each mixing.

The average values for the tensile strength obtained were :—

(*a*) For Pure Cement Briquettes—
556 lbs. per sq. in. at 7 days.
624 ,, ,, ,, ,, ,, 28 ,,

(*b*) For Briquettes using 3 sand and 1 cement—
178 lbs. per sq. in. at 7 days.
300 ,, ,, ,, ,, ,, 28 ,,

Method of Mixing.

All the mixing was done by weight because in the author's opinion a more accurate result is obtained, and so that the results would have some definite working value the mixture adopted was that represented by the much used : 1 cement, 2 sand, and

4 stone. By weight the following are the proportions required: 1 cement, 1·77 sand and 4·51 stone.

The amount of water used was slightly different for different temperatures of test and the following were used: 10·25 per cent. for temperature 55° Fahr., 10·5 per cent. for temperature 70° Fahr., 10·75 per cent. for temperature 85° Fahr., and 11 per cent. for temperature 100° Fahr. All these percentages are of the total value of the constituent dry materials.

By using the above method of mixing a very accurate " mix " ought to be obtained, and the author was disappointed that the results recorded were not more consistent.

Six specimens were made and tested, but only the four highest values were tabulated.

The time of mixing was kept approximately constant and the various briquettes were moulded in a steel form to the size of 4½ in. × 4½ in. × 4½ in.

Temperature Adopted.

Only 4 temperatures were used in the test, namely 55° Fahr., 70° Fahr., 85° Fahr. and 100° Fahr. These temperatures are usual working temperatures at different seasons in South Africa.

Conditions of Atmosphere in Thermostat.

To keep the atmosphere in the thermostat as dry as possible flat trays (perforated) containing calcium chloride were placed on special shelves in the thermostat whilst the saturated—or humid—condition was obtained by filling similar trays with water.

Age of Test Specimens.

Six different ages of specimens were used, namely: 3 days, 7 days, 10 days, 14 days, 21 days, and 28 days. The results obtained are shown in Tables I, II, III, and IV.

Conclusions.

The author believes that the following conclusions can be stated definitely.

1. Under uniform temperature conditions there is a general increase in strength during the first 28 days of ageing.

2. Concrete maintained at a temperature of 70° Fahr. will have a very much greater strength in a week " after mix " than concrete at a temperature of 40° Fahr.

3. There were also indications that the strength of concrete decreases very rapidly if allowed to age in a " dry " atmosphere. The author is convinced that disintegration would take place if the time were increased.

4. It is imperative in tropical and sub-tropical countries to take account of atmospheric conditions, especially in such work as concrete water-towers, concrete piers for bridges, etc., etc.

Further Researches.

As stated above, the author was able to have the advice of Mr. Cooper in 1910. The author felt sure at that time that the use of concrete mixers in some cases had been the cause of the failure of concrete put into structures. A more or less sloppy mixture is necessary for the successful use of mixers.

After a great deal of discussion, such as would only be possible under the conditions pertaining at that time—namely thirty days at sea with a concrete expert—the author concluded that there must be a definite quantity of water to be used in order to obtain economically the best mixture.

Bearing in mind the great range of temperature and humidity in South Africa, further experiments in concrete were made to include these two factors as well as water content.

From a paper read by Mr. R. K. Skelton before the Connecticut Society of Engineers in 1915, it appeared that the critical water content under the conditions he experimented was 27·5 per cent. by weight of the quantity of *cement* used.

The author felt that humidity would alter this figure and so conducted his experiments giving the range of water content between 20 per cent. to 30 per cent. by weight of the quantity of cement used.

The materials used in these experiments were exactly the same as those for the "Preliminary Experiments." The temperatures adopted were the same as also the method of mixing, excepting only that the mixture was arranged to be equivalent to a mixture of: 4 stone, 2 sand and 1 cement by volume.

Tabulation of Results.

There were six specimens prepared and tested for each percentage of water used, for each age of specimen, for each temperature, and for each condition of humidity, making a total of 3,128 specimens tested.

For each condition the four highest readings were taken and results duly tabulated, and plotted out in curves.

Conclusions from Curves.

(1) The curves bear out definitely the author's conclusions arrived at by the preliminary experiments.

(2) That there is a definite quantity of water which gives the maximum strength of concrete.

(3) That this quantity depends on the humidity and temperature of the atmosphere.

(4) That in using concrete mixers contractors must be careful of the quantity of water used, and consulting engineers should specify this quantity.

(5) That consulting engineers should examine the stone and sand before writing the specification for concrete.

(6) That it is essential that the average humidity and temperature of the position where the concrete is to be fixed should be known.

Need for Further Research.

The author hopes to continue these experiments for varying mixtures of aggregate and cement and for different kinds of aggregate and sand; for he feels that cement concrete must in the future be far more scientifically handled than it has been in the past.

DISCUSSION.

Dr. Owens asked for information on the relative weights of the specimens which were tested in humid and dry air. Apparently the only possible difference could have been due to difference in water contents resulting from either the humidity or the effect of the dry air, and that should be brought out by weight. He also pointed out that the fact that a specimen placed in dry air does not necessarily mean that it is subjected to the greatest possible evaporation, as one of the most important factors covering evaporation is wind, the movement of the air. In fact, if the specimens were placed in still air, he did not think they would be subjected to the greatest possible evaporation, and it is possible that placed in less dry air with more movement he would have got quite different results. The important point seems to be that it is not quite justifiable to assume that the curves on the dry side represent the conditions which would be got under all circumstances of drying.

Mr. W. A. Green asked the author whether in his proportions by weight, the sand and the granite were dried before they were weighed. Were they absolutely dry? He spoke of the water content being taken after the materials were soaked, but were they dried first?

Professor E. R. Matthews said though he had not studied the action and the effect of humidity on concrete, he had studied a subject which is very similar, or rather on the same lines; that is the action of excessive heat and the action of excessive cold on concrete. He said sufficient attention had not been given to these important things. He, the speaker, carried out a number of experiments lasting two years, and his conclusions were as follows: Light frost, not exceeding 3·7 degrees of frost, does not affect freshly mixed concrete, but a temperature of 17 degrees of frost does seriously affect the concrete; so much so that it reduces its strength considerably. Concrete under those conditions gave a much less favourable result to compression and tension than in the ordinary way. The 3·7 degrees of frost, continued for half an hour, does not affect the concrete, but 17 degrees of frost continuously for several hours would seriously cripple the concrete, and it can never recover.

If the reinforced concrete structures are designed in England for some country across the sea, somewhere where they are subject to severe frost, it is quite easy for the engineer to have a great difficulty in knowing what amount of water to mix with the concrete, and how to arrange so that no mixing is done when the temperature is below a certain point.

Mr. C. H. Colson mentioned that there was another side to this matter: heat will make concrete set considerably quicker. So that if the materials were heated the trouble of the setting is got rid of altogether. It is quite ordinary in mixing concrete pipes, to put them into a furnace when they are quite wet and heat them up.

Mr. S. Bylander said that some information might be interesting on the question of concrete setting in wet weather. He had had the supervision of concrete work in Canada at temperatures varying from 80 degrees above to 30 below Zero. He had noticed that in hot weather, say at 80, 90, or 95 degrees, the concrete had dried out very quickly; and it became necessary to protect the concrete from the hot wind. Where the concrete was not so protected he had noticed that the surface, say a quarter of an inch on the top, had dried off very quickly and would not harden. With regard to concrete placed in wet weather, he had made a number of tests to ascertain what was the real effect of freezing the concrete. He had had a series of nine cubes, three in a set, and had subjected these to various conditions. The temperature of the air, when the concrete was placed, had been 50 degrees below Zero. One set of three cubes had been placed on the wall and subjected to the wind and the winter weather for about four months. It had been tested in the following June, after it had been frozen for about four months, and had the opportunity of setting off and then been thawed up. That concrete had shown a strength of about half what it would have had if properly matured. Other cubes had been placed in a warm room, and the effect of freezing only for an hour or two ascertained The effect seemed to be that if the concrete was frozen immediately, thawed up and let freeze again the result was very bad. Concrete which had been properly protected, particularly in great masses, and left for at least twelve hours to set before it froze, would attain a set practically the same as if properly matured. But one precaution must be taken, the gravel and the sand and other materials must be heated before mixing the concrete, and the structure must be strutted up and supported during the winter months until the concrete had time to set during the early summer.

Mr. White said he had been in Winnipeg when several thousand yards of concrete had been poured under very severe winter conditions; and it had been found that concrete done during the winter, if properly safeguarded, was quite serviceable. The method adopted in big work had been to cover with a tarpaulin and set coke fires below. It had also been thought that the concrete, by its chemical action, would generate a heat of its own; which would rather take away the effect of the frost. There had been one or two structures in Winnipeg badly constructed during the winter season. From these the boards had been taken away during the winter season, and when the spring came along and the thaw set in, those wonderfully strong-looking jobs had gradually melted away.

MEMORANDA.

Independent Floor-Beams and Slab in New Concrete Arch Bridge.—In order to simplify the floor forms in the construction of a large concrete arch bridge now being built in Pittsburgh, the engineers designed the slab and floor-beams as independent elements, the slab to rest on top of the completed floor-beams. In construction, the spandrel columns resting on the arch ribs and the floor-beams will be concreted in forms built up from the ribs and, subsequently, after removal of these forms, the forms for the floor slab and the fascia stringers on either side will be built between the floor-beams and supported by them. This avoids the necessity of carrying the heavy floor forms and slab by supports extended up from the arch rib. No definite plane of separation between slab and beams is provided except that formed by the construction joint, and on the contrary the floor-beam diagonal reinforcement is allowed to extend up into the slab. But the beam is designed as though it terminated at the bottom line of the slab rather than as a beam extending to the top of the slab or as a T-beam utilising part of the slab for compression area.

The bridge is a two-rib parabolic structure with open spandrels, of 267 ft. 4¼-in. span between faces of abutments, or 279 ft. between theoretical springing lines, and 57 ft. theoretical rise, or 55·89 ft. rise of intrados. The floor panels are 15½ ft. long, centre to centre of floor-beams. The two arch ribs, 26 ft. apart on centres, are each 8 ft. wide, with a crown depth of 6¼ ft. They are reinforced with eight angles 6 × 4 × ¾ in., connected at intervals of 3 ft. by encircling tie bars 2¾ × ⅜ in.—*Engineering News Record.*

The Highways of the United States.—Dealing with the problem of highway construction in the United States for 1921-22 and reviewing the work done, a writer in the *Engineering News Record* says that in 1921, "Concrete maintained its lead as the favoured material for paved roads. Even including waterbound macadam, the mileage of concrete was considerably more than half the total. . . . Certain states appear with unusual mileages of concrete construction:—Pennsylvania, 612 miles; Illinois, 400 miles; New York, 367 miles, and Wisconsin, 340 miles. It is more significant, however, that States only just beginning the development of paved roads have concentrated even more closely on concrete. In such states as South Carolina, Nevada, Arizona, Colorado and New Mexico, practically nothing but concrete pavement was constructed."

CONCRETING IN COLD WEATHER.

(*Contributed.*)

The days when the heating of concrete during setting was considered to be an indication of unsound cement containing free lime are past, and it is now generally recognised that the setting of cement is a chemical action evolving heat, which is manifested by raising the temperature of the cement. There are, however, probably few who appreciate the value of this heat in preserving concrete in winter weather from the attack of frost, and some useful investigations by Tokujiro Yoshida upon the rate of cooling of fresh concrete in freezing weather have just been published in Bulletin No. 123 of the University of Illinois Engineering Experiment Station.

The method of experiment consisted in casting concrete blocks 12 in. by 12 in. horizontal section and of depths varying from 4 in. to 20 in. in moulds of $1\frac{1}{2}$ in. pine boards, the moulds being contained in another wooden box 3 ft. square and 3 ft. deep, and the intervening spaces between the mould and the outer box being filled with sawdust. Thermo-couples were inserted in the concrete at various depths from the surface, and the insulated moulds containing the concrete were placed within 20 minutes of mixing in a cold storage room at —10° C. The concrete blocks were thus exposed to the cold on one surface only, all other surfaces being well insulated. Temperatures recorded by the thermo-couples where observed at intervals.

Typical curves of cooling are shown in *Fig.* 1, from which it will be seen that starting with a concrete at 20° C. (68° F.) in a temperature of —10° C. (14° F.), the freezing point at the surface is not reached until after a lapse of 24 hours, while at 15 cm. (6 in.) below the surface freezing point is not reached under 40 hours. That this is not due altogether to a naturally slow rate of cooling is seen by reference to *Fig.* 2, which shows the rise in temperature in 12 in. cubes of concrete kept at ordinary laboratory temperature and insulated on all six sides.

The practical conclusion to be drawn from these observations is that the heat generated during the setting of concrete should be conserved to help the concrete to resist the action of frost. The effect of so doing is cumulative, because by maintaining a high temperature within the concrete, the harder it becomes, and the harder the concrete the less it can be harmed by frost. In this connection the results of further experiments recorded graphically in *Fig.* 3 are of interest. Here it will be observed from the results of Experiment No. 7 that a concrete surface submitted to an air current of 10 miles per hour in a cold storage chamber at —10° C. cooled much more rapidly than a concrete in still air (cp. Experiment No. 5), while covering with wood or canvas was of great value in retaining the heat of the concrete, as even the surface temperature of the concrete did not descend to freezing point in 48 hours. It should be noted, however, that in these cases care was taken to prevent circulation of air below the covering.

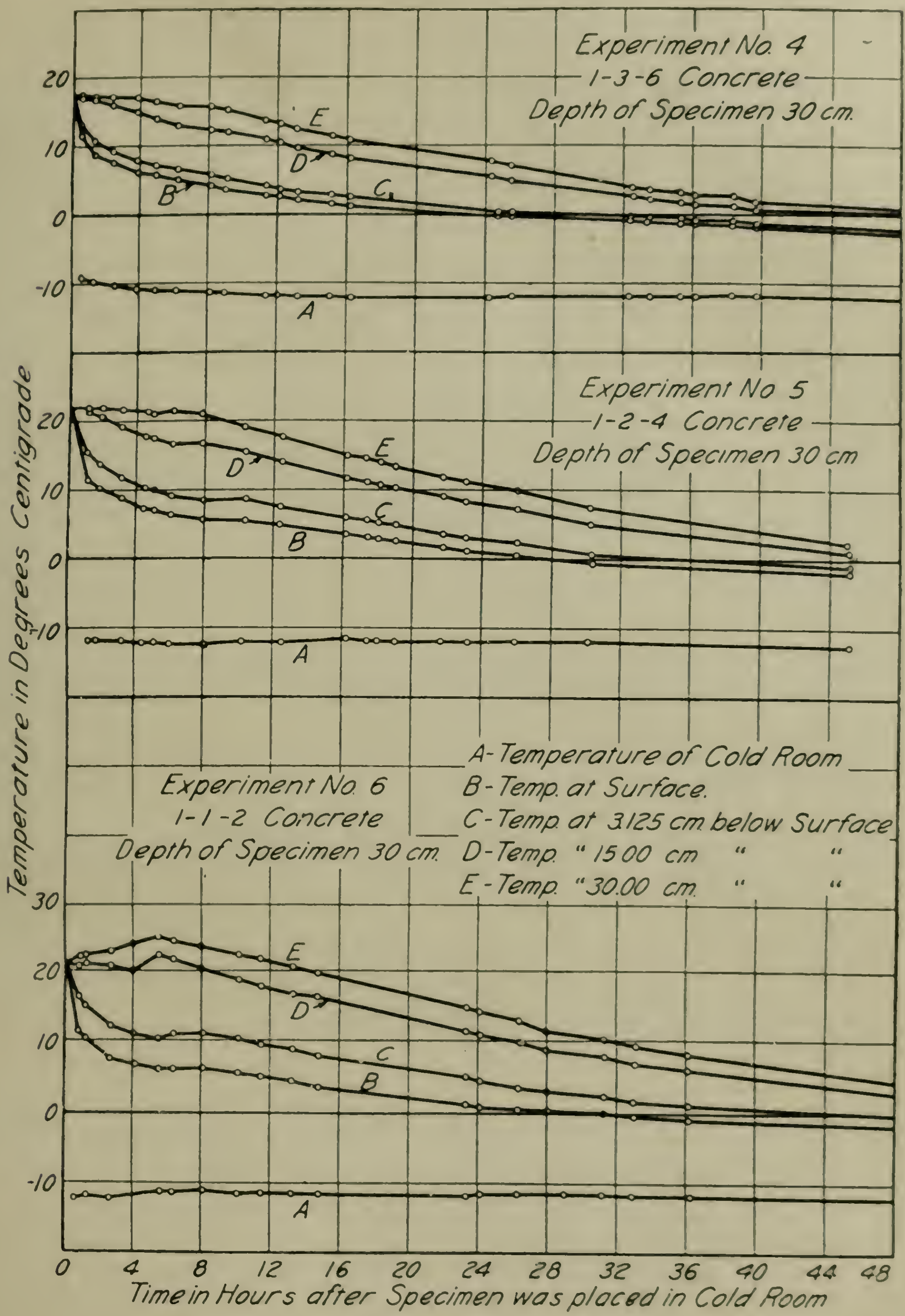


FIG. 1. CURVES OF COOLING EXPERIMENTS 4, 5 AND 6.

In drawing conclusions from these experiments it needs to be emphasised that the concrete was at a fairly high temperature when mixed—viz. about

68° F.—and if concreting is to be done successfully in frosty weather it is necessary to heat the materials of which it is composed. This being done, it is evident that by protection of the concrete on all sides by means such as shuttering, there is little danger to be apprehended from any low temperature likely to occur in this country.

In Tokujiro Yoshida's paper the experimental results are mathematically analysed and applied with the idea of predicting the temperature of freshly laid concrete subjected to frost. For example, it is calculated that mass concrete within shuttering and with one exposed surface, if at a commencing temperature of 60° F. and in still air at 10° F., would not reach freezing point at the surface

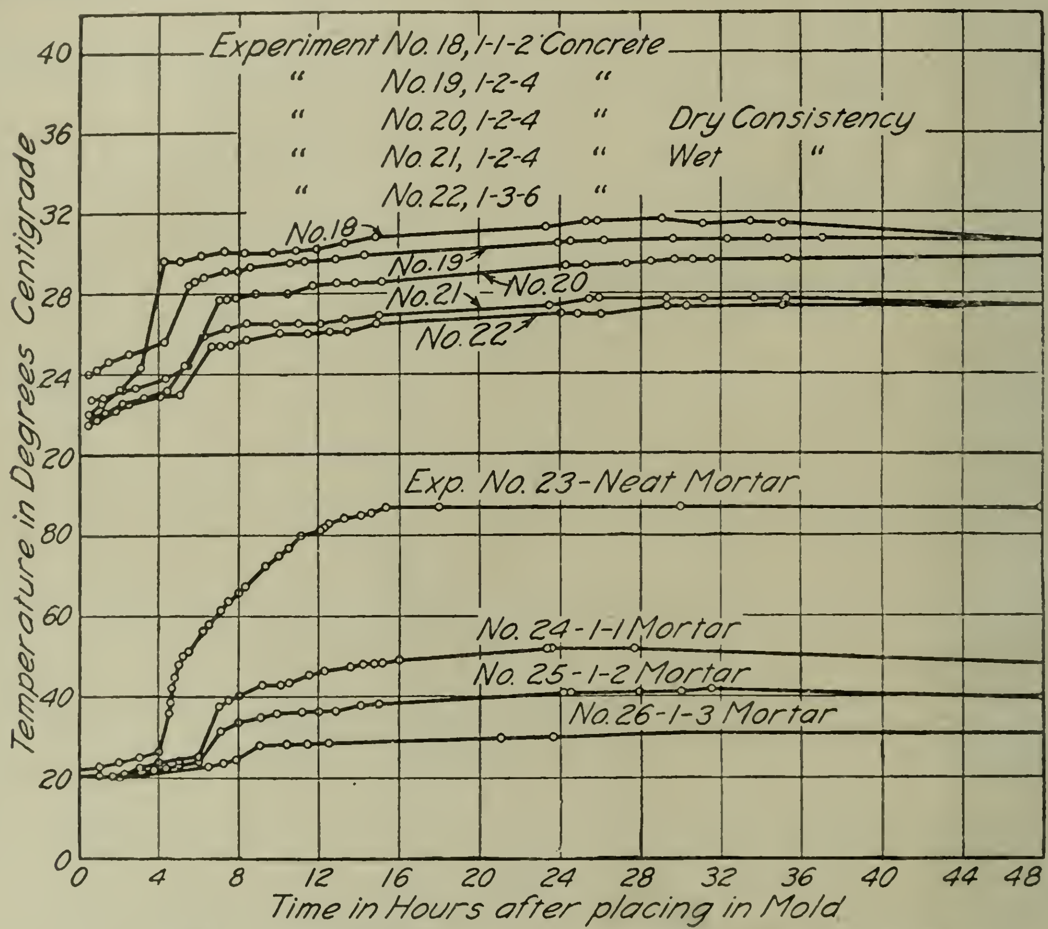


Fig. 2. Diagram showing Rise in Temperature during Setting of Concrete and Mortar.

for 18 hours, while at 12 hours the surface temperature would be 35° F., and the temperature 4 in. below the surface 45° F. If the surface of the concrete be covered with a board 1 in. thick, the surface temperature after 72 hours is calculated at 35° F. If the concrete is in the form of a thin wall or slab the rate of cooling is greater, and it is calculated, for example, that in a 16-in. wall between ¾-in. shuttering with concrete at a commencing temperature of 60° F., the temperature at the surface 36 hours after pouring will be 36° F. and at the centre of the wall, 41° F., after the same lapse of time, when the atmosphere is at 10° F.

Another purpose for which the data upon the subject may be used is to calculate the temperature to which the concrete materials must be heated to prevent freezing occurring in a given time at a given atmospheric temperature.

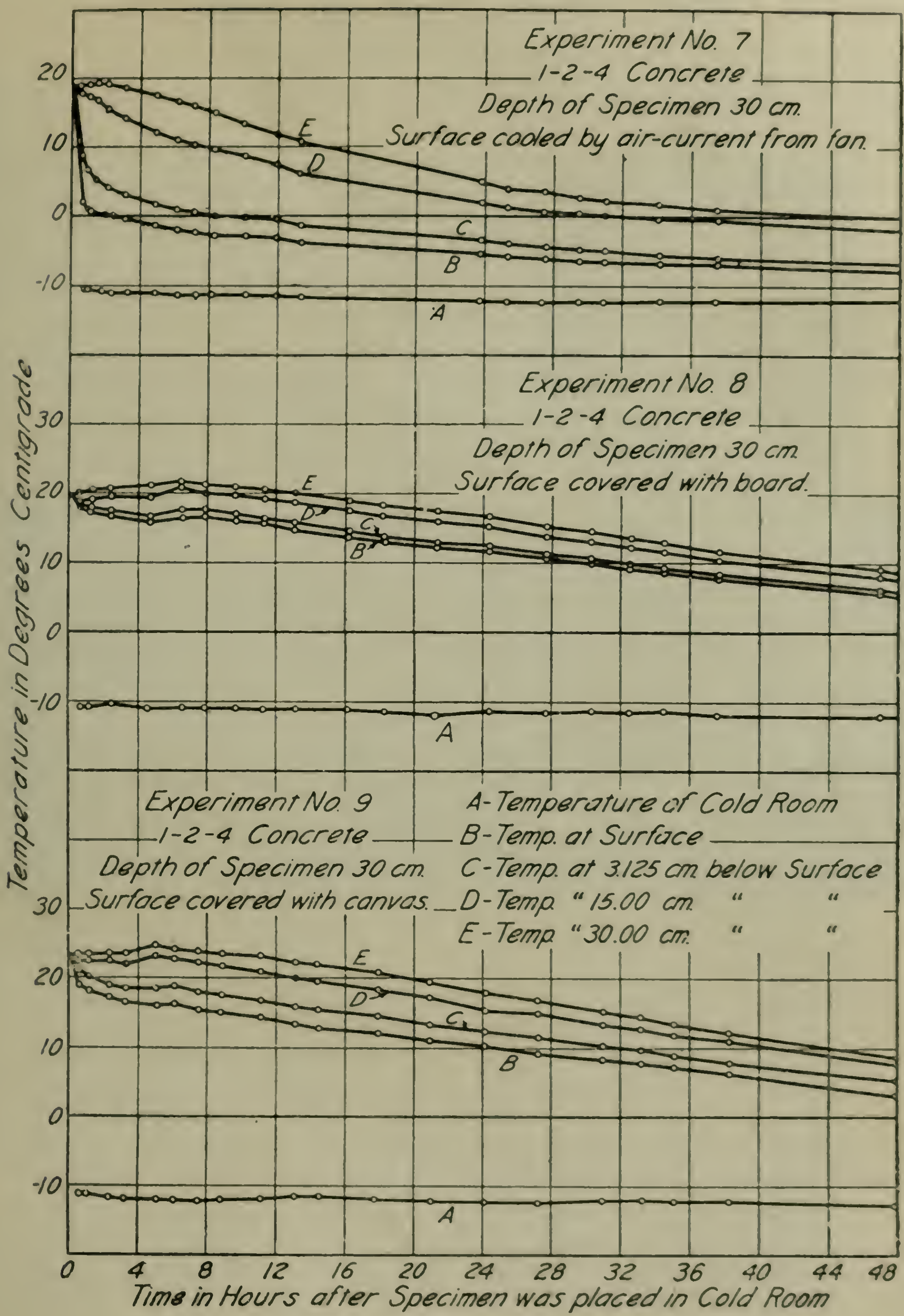


FIG. 3. CURVES OF COOLING EXPERIMENTS 7, 8 AND 9.

REINFORCED CONCRETE TANKS FOR STORAGE AND FERMENTING OF BEER.

By V. ELMONT, B.Sc., M.I.Mech.E.

THE general advantages gained by building containers for beer in reinforced concrete and the structural principles involved in the design of them are the same as apply to other structures of that material. But very often odd shapes and forms have to be given to concrete tanks in order to make the fullest use of every cube inch of an existing building into which the tanks have to be fitted. The actual conditions of each individual brewery have naturally to be studied very carefully and the vats designed to utilise the space allotted for storage and fermenting purposes in the most efficient manner.

The vats are, as a rule, placed on supports 20–25 in. in height, the space underneath being used as tapping room. The inside height of the fermenting tanks is approximately 6 to 7 ft., depending on the height and best possible utilisation of the room where the tanks are to be placed.

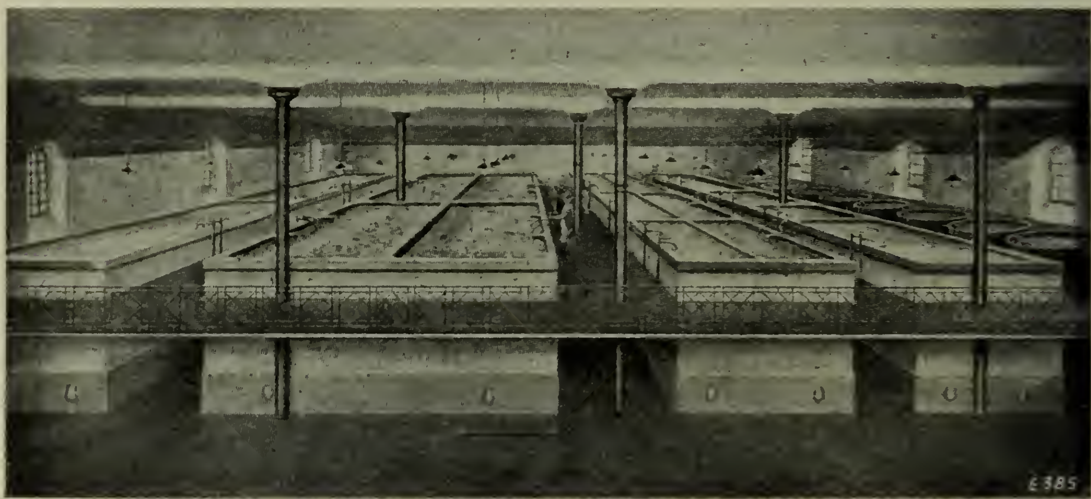


FIG. 1. FERMENTING VATS, CAPACITY 250,000 GALLONS.

Reinforced concrete has been used as material for storage and fermenting vats for beer during twelve to fifteen years and the results obtained prove that concrete beer tanks, when designed and constructed in accordance with best engineering practice, give complete satisfaction. Some breweries have proceeded in the manner that they have built tanks of wood, steel and concrete at the same time in order to compare the various features involved in a practical and conclusive manner. As a result of the comparison they are now replacing existing wooden tanks and constructing all new tanks in reinforced concrete.

The accompanying illustrations show the different modes of construction for concrete beer tanks and the economy of space they effect. All the tanks depicted have been in use for several years. In *Fig.* 1 is seen a fermenting cellar, holding about 250,000 gals.; the concrete tanks are in the usual manner lifted 25 in. from the ground and working platforms arranged at a suitable level alongside the tanks. The two rectangular vats in *Fig.* 2 contain each 33,000 gals. In *Fig.* 3 is seen the end wall of a 19,000 gallon tank and the various attachments required for the pipe connections.

A number of vats have been designed as vertical and horizontal cylinders.

In *Fig.* 4 is shown a system of thirty-six cylindrical tanks with a total capacity of 100,000 gals.

Fig. 5 gives an idea of how reinforced concrete vats can be designed to fit into existing storage rooms by shaping the walls and ceiling accordingly. Another example, showing the adaptability of concrete tanks, will be seen in *Fig.* 6 (50,000

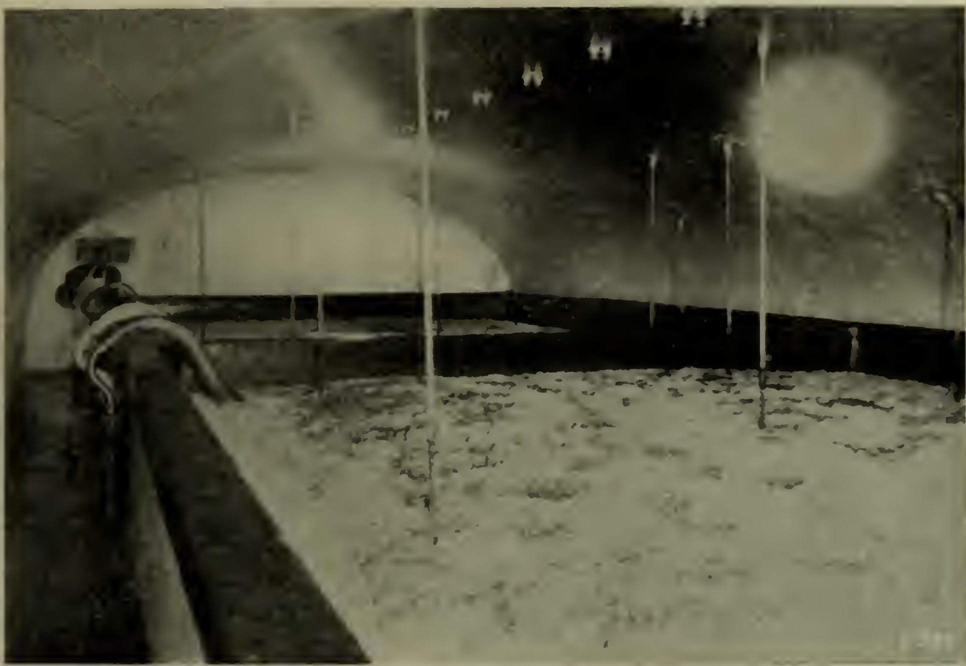


FIG. 2. VIEW OF FERMENTING VATS OF 33,000 GALLON CAPACITY.

FIG. 3. END WALLS OF TANKS CONTAINING 19,000 GALLONS.

gals. total). The tanks in *Figs.* 5 and 6 are storage tanks and constructed to withstand the pressure of the fluid and, in addition thereto, one half of one atmosphere of carbonic acid pressure.

The inside surfaces of all the tanks shown are lined with a special material—

invented by the Austrian engineer Rostock—which is immune against acids and alkalies, and the beer is in no way affected by it. This system has during a long period been applied to beer tanks, the total capacity of them amounting to several millions of gallons. No special layers of tar paper, expanded metal or the like are required for attaching the lining to the concrete, thus obviating all complications due to such procedures. The sides of the walls which are in contact with the beer are entirely saturated with the impregnating material and an evenly smooth and poreless surface obtained. It is very hard and elastic and offers great resistance against any mechanical damage; should the lining be injured repairs can be attended to by the staff of the brewery and, consequently, working security and independence from the vat builders are assured.

The interior lining is formed in the following manner: First are applied

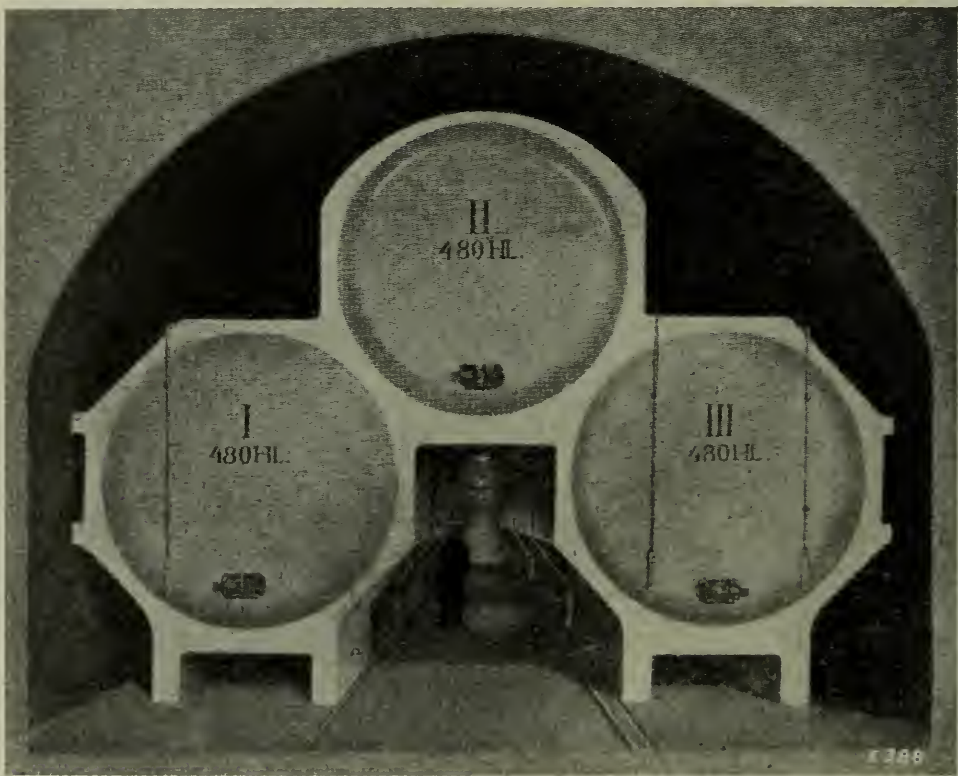


Fig. 4. Cylindrical Vats. Total Capacity, 100,000 Gallons.

several layers of cement mortar coats, each applied by special methods and containing certain admixtures in such proportions as to render the surface smooth and absolutely impervious. The surface of this plaster is able to resist the heating necessary for the application of the special finishing coat which permanently impregnates the cement mortar and at the same time forms a sort of enamel of great strength and resiliency. It is on this enamel that the usefulness of the vats depends, since it gives the same security against infection of the beer as, for instance, expensive metal linings such as copper and aluminium.

The method of procedure in cleaning these vats is the same as for wooden vats; only the large concrete vats with their regular smooth surfaces require much less time to clean. Experience shows that the cost of labour for cleaning is reduced by 50 to 60 per cent.

In conclusion it should be mentioned that as regards cooling, concrete tanks

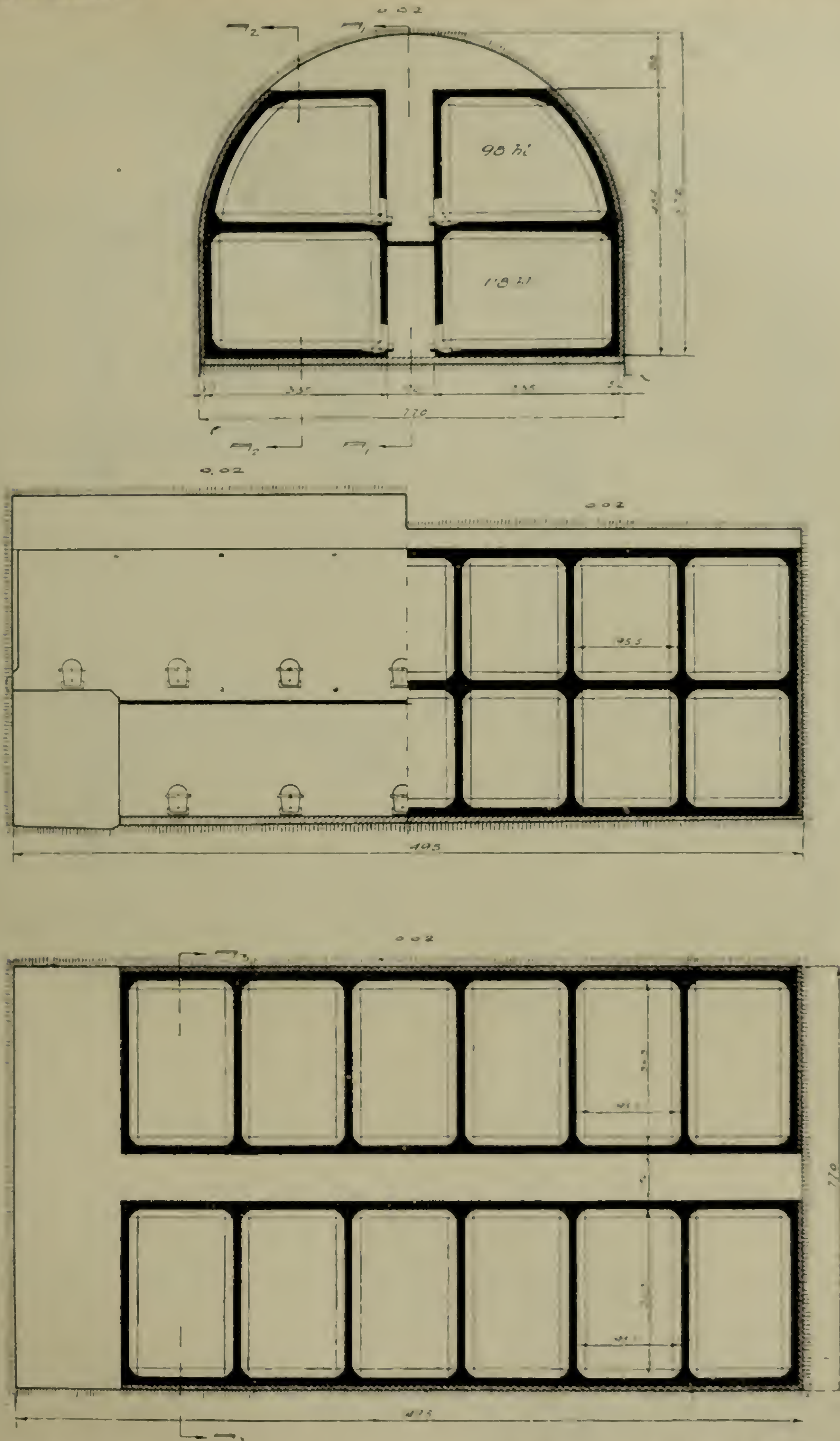
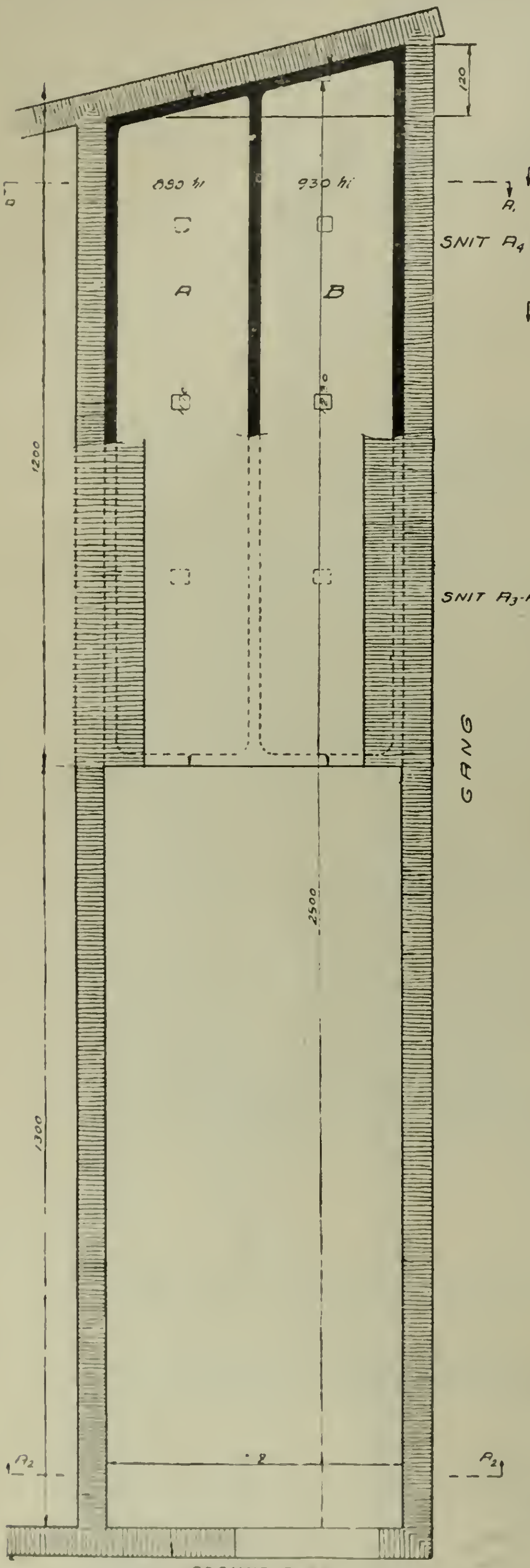
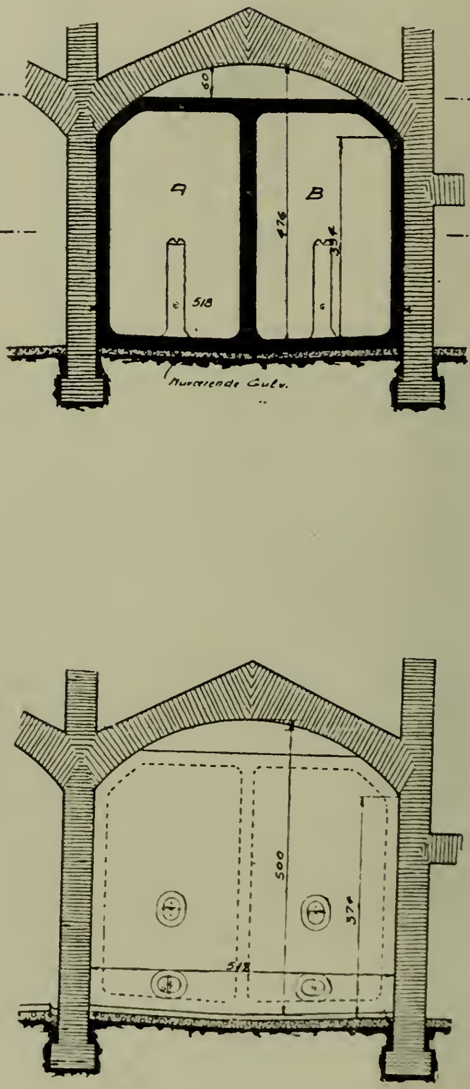


Fig. 5. Plan and Sections of Reinforced Concrete Tanks for Storage of Beer under Pressure.

offer a special advantage. The air space to be cooled in a fermenting cellar fitted with these tanks is only one-third as compared with a cellar of equal capacity



GROUND PLAN.

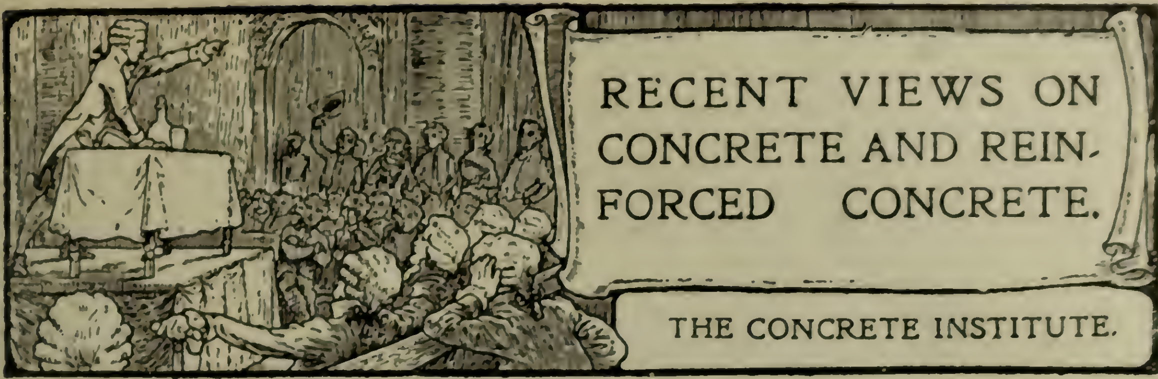


SECTIONS.

FIG. 6. REINFORCED CONCRETE TANKS FOR STORAGE OF BEER UNDER PRESSURE.

fitted with wooden vats, owing to the concrete vats being placed closely together. Consequently a great saving in cost of installation and working expenses is realised.

The cooling of the vats is effected through the usual system of cooling pipes, fitted in accordance with the shape of the vats so as to obtain an equal distribution of the cooling surface.



REINFORCED CONCRETE IN THE CONSTRUCTION OF BY-PRODUCT COKE OVEN PLANTS.

By "MANAGER."

In a recent number of the "Gas World" an article appeared signed "Manager" dealing with the above subject, and as the article may have some interest for our readers we give a short abstract below.

Comparing the descriptions of recently built by-product coke oven plants with those constructed a number of years back, one cannot fail to notice a continually increasing application of reinforced concrete for buildings, tanks, bunkers, foundations, etc. Even after this material had found its way well into other parts of the industry its use for the building of parts of coking plants did not become general until a few years ago, when its importance and usefulness were fully realised by the respective engineers and architects. To-day it is used to replace iron constructions to such an extent that it is worth while to go into the matter.

Advantages and Disadvantages.—The introduction of reinforced concrete in the construction of plants was, in the first instance, due to difficulties in obtaining supplies of steel structures in the time specified for the completion of the plant, and it is certainly a point which speaks very much in favour of the application of reinforced concrete that the requisite materials can generally be obtained without difficulties or delay; further, that the design of ordinary structures does not offer special difficulties to the engineer with average education, and that, beyond close supervision, no skilled labour need be employed for the erecting and building.

On coking plants reinforced concrete offers the great advantage that it does not require any upkeep. It is not affected by the gases and vapours escaping from such plants, while steel corrodes rapidly if not kept properly coated with paint. Tanks built of this material are watertight, and the liquid does not affect the cement like it does iron or steel. Its greatest disadvantage is that alterations are practically impossible. Large structures must, therefore, be well laid out in every respect to avoid alterations. Reinforced concrete cannot be applied to such parts of the plant which have too high a temperature, and special precautions must be taken where structures are likely to be subjected to great changes of temperature. As the difference of the expansion coefficient of mild steel and cement is very small, being 0·0014 and 0·0017 at 100° C. respectively, it would appear that even a fairly high temperature should not have a detrimental effect upon reinforced concrete, as long as the changes of temperature are not too rapid.

Washeries.—Commencing at the coal tip of the washery, this is generally a pit underneath the truck rails, having a capacity of fifteen to twenty-five tons of coal. It is preferably made of concrete, to exclude surface water, and properly smoothed over to facilitate the sliding down of the coal. If, during building, the lower part cannot be kept free of water by a temporary pit, arranged close by to drain the ground, a piece of pipe may be set into the concrete bottom with its flange projecting a little, so that the bolts can be introduced through the flange holes. After the cement has set hard the water is pumped out, and the pipe may be closed up by a blank flange.

The whole washery buildings are nowadays more and more made completely of reinforced concrete, and they offer a much better appearance than the washeries of earlier date, which generally consisted of steel structures walled up with bricks. A disadvantage which has often been felt in coal washeries was when it became necessary to cross a wall by an additional pipe line, etc. On the other hand, there is the advantage of the settling and elevator pits for wet coal inside the washery building, which is so manifest that the designers are not likely to depart again from reinforced concrete for the purpose. To avoid the former disadvantage and have the latter advantage, many builders construct the washery of reinforced concrete up to the floor carrying the machinery, thus containing all the necessary pits, while the upper part of the building is made of steel and red bricks. Such a construction, however, somehow spoils the appearance of the building, and the course is often adopted to make the lower part of the building entirely of reinforced concrete and also the outer walls of the upper part right up to the roof, while the partition walls in the upper portions are made of steel and bricks or brickwork only. Concrete roofs on a washery, as well as on any other buildings in connection with a coking plant, are a great advantage, as they do not require any upkeep. Settling ponds outside the washery are almost without exception built of reinforced concrete.

Oven Structures.—In the building of ovens reinforced concrete is now extensively used for those parts of the substructure which used to be built of ordinary brickwork. It has always been the practice to build a battery upon a concrete bed several feet in thickness, laid on the solid ground. Nowadays all those parts of the substructure which do not get very warm are made of reinforced concrete. As the battery expands more than the adjacent coke and machine benches, special provision must be made to allow for movement without disturbing the concrete. Coke benches and machine benches built of reinforced concrete offer the great advantage of being perfectly watertight, so that the room underneath the benches can be advantageously utilised for storing all sorts of materials. The successful introduction of the so-called piling system has made it possible to build batteries and plants on bad ground by ramming in concrete piles which carry a concrete raft, forming a solid foundation.

The coke oven chimney is always built of ordinary bricks, and to a certain height lined with firebricks. Concrete is extensively used as a foundation up to the chimney base, but I do not know of a whole coke oven chimney having been built of reinforced concrete.

The top part of the ovens is too hot, so that concrete cannot be applied as a cover over the whole battery. It is, however, extensively used for bridges connecting a battery with the coal hopper or interconnecting several batteries. The concrete beams of such bridges must rest freely in gaps provided in the end pillars of the battery upon greased wrought-iron plates, to allow the battery to expand independently of the bridges.

The coal bunker which supplies the ovens is nearly always built of reinforced concrete nowadays. Probably the erection of coal bunkers of this construction formed the introduction of this material on coke oven plants. The upkeep as well as the erection of steel bunkers is, owing to their height and to the water contained in the coal, rather high, while concrete bunkers can be built at a lower price and there is no upkeep to pay for.

Underground Tanks.—In the by-product plant concrete is largely used for the foundations on which the condensing apparatus rests, such as coolers, tar extractors, scrubbers, etc. Tar and liquor tanks are frequently made of reinforced concrete now, whether below or above surface level. On many plants a large tank-shaped pit, either round or square, is dug and built with reinforced concrete so as to prevent any surface water from draining through. In this pit is placed the tar and liquor well, of riveted steel plates. The steel tank is thus accessible from the sides. This arrangement can, however, be much simplified by building the retaining walls pretty strong, covering up the top, and using the concrete tank for tar and liquor storage. In recent years store and decanting tanks built above surface level seem to have come into favour; they can also be built entirely of reinforced concrete. In the case of surface tanks the mixture of tar and liquor accumulates in a small collecting tank below surface level, and is from there pumped continually into the decanting tank. This collecting tank may also be built of the same material. Tar and liquor tanks should, after they have been built and cleaned, be smoothed over, and, properly dry, be given two or three coats of boiling tar, which will soak into the cement, set very hard, and render the material water-tight. The author does not recommend concrete for the tar-pit forming the seal under the vertical portion of the crude gas main entering the by-product plant, as pitch and naphthalene settle out in this tank and must be removed by means of scrapers to keep the pit clean. The pitch sticks to cement much more than to steel plates; as the cement wears much more quickly under the effect of the scrapers and then offers a rough surface, the tar pit should be made of steel plates. On plants which are provided with a gasholder the tank for the bell may be made of reinforced concrete.

Buildings.—The buildings of the by-product plant are by many coke oven builders built entirely of reinforced concrete, and look decidedly better than such built of red bricks; they are much cheaper and more expeditiously erected than those built of dressed stones with so-called hammer-poled facings. The sulphate house floor receives a layer of concrete, the thickness of which depends on the condition of the ground. On a good clay soil a thickness of 6 in. is quite ample. The concrete receives a thin layer of asphalt, on which are placed acid-resisting clay tiles. The joints of the tiles are filled with hot asphalt and smoothed over by drawing bent red-hot bars along the joints after the floor has been completed. It should again be emphasised that, although asphalt appears to be somewhat expensive at first, it offers the only really suitable floor for factories where acid is likely to be spilled. Coal-tar pitch breaks up very quickly and, once the acid comes in touch with the cement, raises parts of the floor and causes a disturbance of the whole floor surface. When re-making a sulphate house floor while the plant is working, it is very difficult to guard against acid spills coming in contact with the concrete while setting and drying, and it is well worth while to spend a little extra money and care in making a satisfactory job at the commencement. The same applies to the upper working stage in the sulphate house which is made in a like manner and tiled.

Mother liquor tanks are also made of concrete smoothed inside, receive several coats of liquid acid-resisting asphalt, and are then covered with sheet lead inside. Their outer bare faces may be made smooth to improve their appearance, and occasionally receive a coat of tar. Concentrated sulphuric acid is stored mostly in cylindrical steel tanks or old boilers, which are much cheaper and more suitable than lead-lined reinforced concrete, especially as they have to resist a certain pressure to transfer the acid from one tank to another.

What has been said about the by-product buildings also applies to the benzole plant. On many such plants oil tanks and often oil coolers must be placed below ground level. For this purpose a large, square, open pit is built of reinforced concrete with a bottom slightly inclined towards one corner, where rain-water can be collected in a small pit and elevated by means of an ejector.

High-Level Tanks.—High-level tanks used for flushing the collecting main and loading tar, as well as the liquor tank to feed the stills, may be placed on the top of a building, and are, of course, covered by a thin raft of reinforced concrete. They may be either placed on the top of the coal washery or coal bunker, but, as this level is generally unnecessarily high, the roofs of a by-product building may be conveniently utilised for the purpose. Owing to the height of the benzole stills, the benzole house gives in most cases sufficiently high a level for the tank mentioned, while on plants which do not recover benzole the height of the exhauster house building must be arranged to suit the purpose.

On tar distilling plants the material adapts itself admirably for the building of pitch beds, from which the pitch can be removed easily, ensuring a clean working.

There are two further applications of the material such as coke oven doors, lined with refractory material and tanks for creosote oil, even with heating arrangements, etc.

There is no doubt that the rapidly developing introduction of reinforced concrete in the construction of by-product coke oven plants has not only simplified the plants and added to their architectural and uniform appearance, but must have also reduced the initial costs of the plant.

ARCHED BRIDGES OF WIDE SPANS.

(*Concluded.*)

A Summary of a Paper read before the Swedish Concrete Institute.

By Dr. F. von EMPERGER.

Some of the illustrations in this part were referred to and dealt with in the December Number, 1921.

FURTHER support of this contention is found in the experiments carried out by M. Mesnager,* the manager of the experimental laboratory in Paris with a model in glass (*Fig.* 14) of a bridge designed by Hennebique over the Rhone near Balme with a 320 ft. span which was carried out in 1916 and which followed in form the one shown in *Fig.* 1 (see Dec., 1921). In the glass model examined under polarised light by Mesnager, the course of the zero line was shown as a broad black strip which clearly marks the plates where a change took place and shows that the conditions in fixed arches are, throughout, similar to those of a fixed beam. By fixing an arch and by the use of skews at the point of fixation a reduction of the span of the carrying structure takes place which must necessarily be followed by a considerable increase in the carrying capacity of the arch, as was proved by the tests of the Austrian Committee on Concrete-Steel Construction.

Under such conditions the actual carrying structure of the arch is confined to the centre of the arch, and a connection exists between these consoles and the centre arch acting in the same way as if a joint were placed there. The difference between a joint proper and this arrangement consists in the fact that with an actual joint the changes in form are concentrated in one point, whereas with the proposed arrangement the permanent changes of form of the concrete arch at the point, can be utilised to distribute the necessary twisting tendency over a large portion of the arch.

The supposed free support, hinge or continuity with support on one point only, is not in accordance with the actual conditions with a concrete-steel structure because the connection of one span to the other or to the abutment does not depend only upon the elasticity or rigidity of the connection, but also upon the permanent change of form in the concrete. The axis of the structure at the points of greatest stresses has a broken form which is followed by a full change of its statics.

Attention may also be called to a further gap in our knowledge of reinforced concrete trusses, which is the reciprocal action of the permanent change of form of the concrete, and which is taken up by the steel rods. This supposed statical arrangement of joints by no means corresponds to the provisional joints mentioned earlier which have to be placed in closer proximity to the abutments, and can be closed up after all secondary tensions have ceased, and so have to be constructed sufficiently strong that this fixation is not interfered with.

In considering the construction of arch hips and how they may be built so as to admit the use of wider spans, and thus to make a more extensive adoption of concrete arch bridges possible, it is necessary to keep in mind the fact that the deadweight of the bridge is the chief factor for the size of arches of large span, and the carried load

* *Annales des Ponts et Chaussées*, Paris, Vol. IV, 1913. An extract of this, by Dr. J. Polivka, was published in *Beton und Eisen*, 1917, page 103.

is of such little importance that a change in it does not necessitate a complete reconstruction, as with steel bridges, but only a small and frequently quite insignificant extension of the permissible load. This is a fact of great importance, particularly for railways, as heavy arched bridges are specially suitable for rail traffic. In constructing a massive arch economically the chief task is to reduce as far as possible the deadweight of the permanent way and the supporting structure. For the latter it is well to choose a rib arch and to reduce the weight of the centre of the arch as far as possible.

To provide a substitute for the crown joint it is necessary to construct the centre of the arch on such slender lines that the reduction of the moments of inertia replaces a

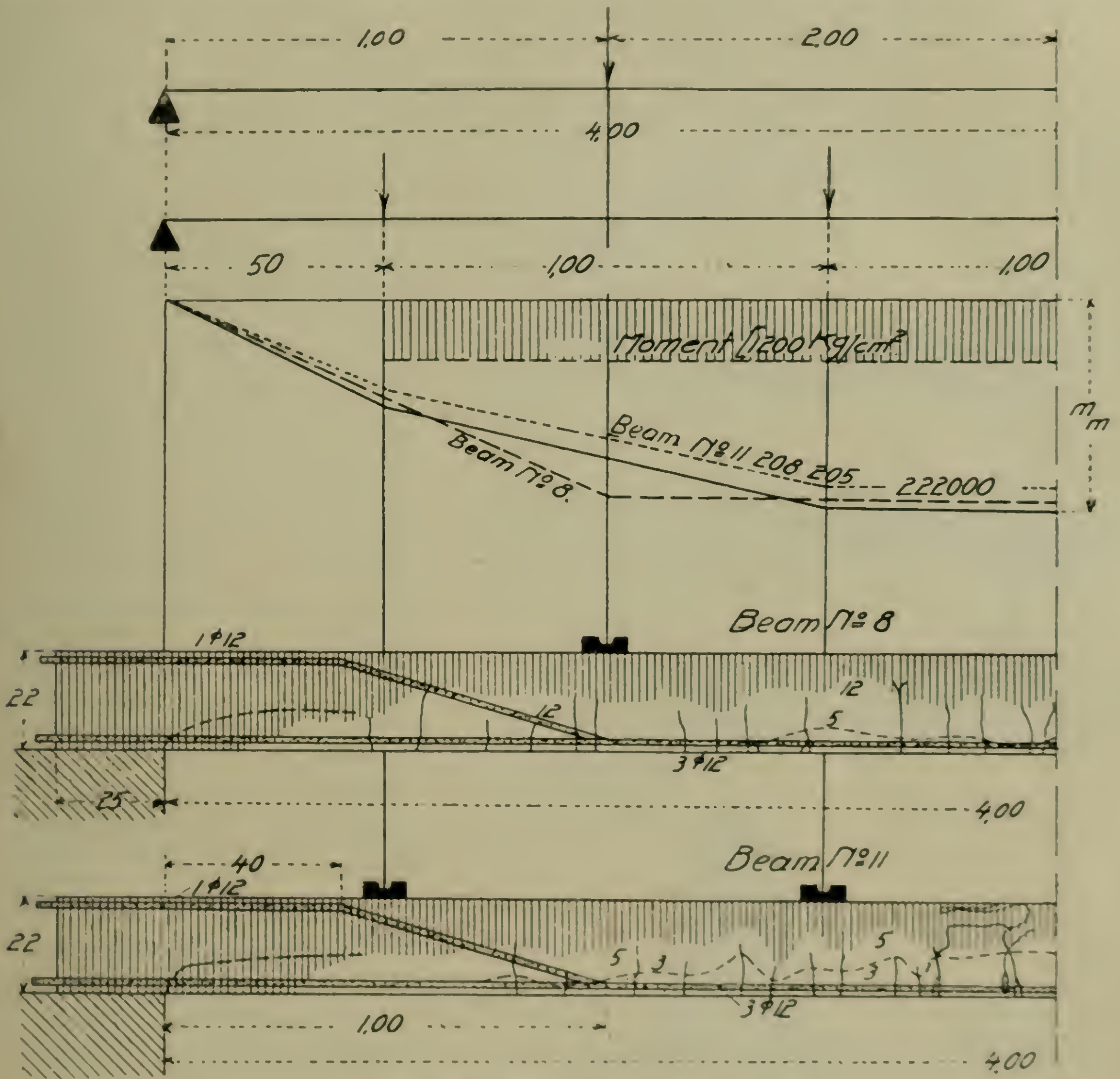


FIG. 8. MOMENTS AND PICTURES OF CRACKS.

joint which would have to take up the changes of temperature. This requirement is in accordance with those of æsthetics which equally demand a slender construction in the centre of the arch. This is made possible by constructing the centre of a particularly resistant material for which there are three possibilities:—

1. The use of cement of the best quality and well graded concrete of high strength.
2. The adoption of "hoopings" which give a high resistance to strains.
3. The use of cores of cast iron or stone of high resistance to pressure. Unfortunately these three aids cannot always be combined.

Tests have proved that if structures are made of different qualities of concrete, but with the same hooping, the effect of the latter will be enormous with poor concrete,

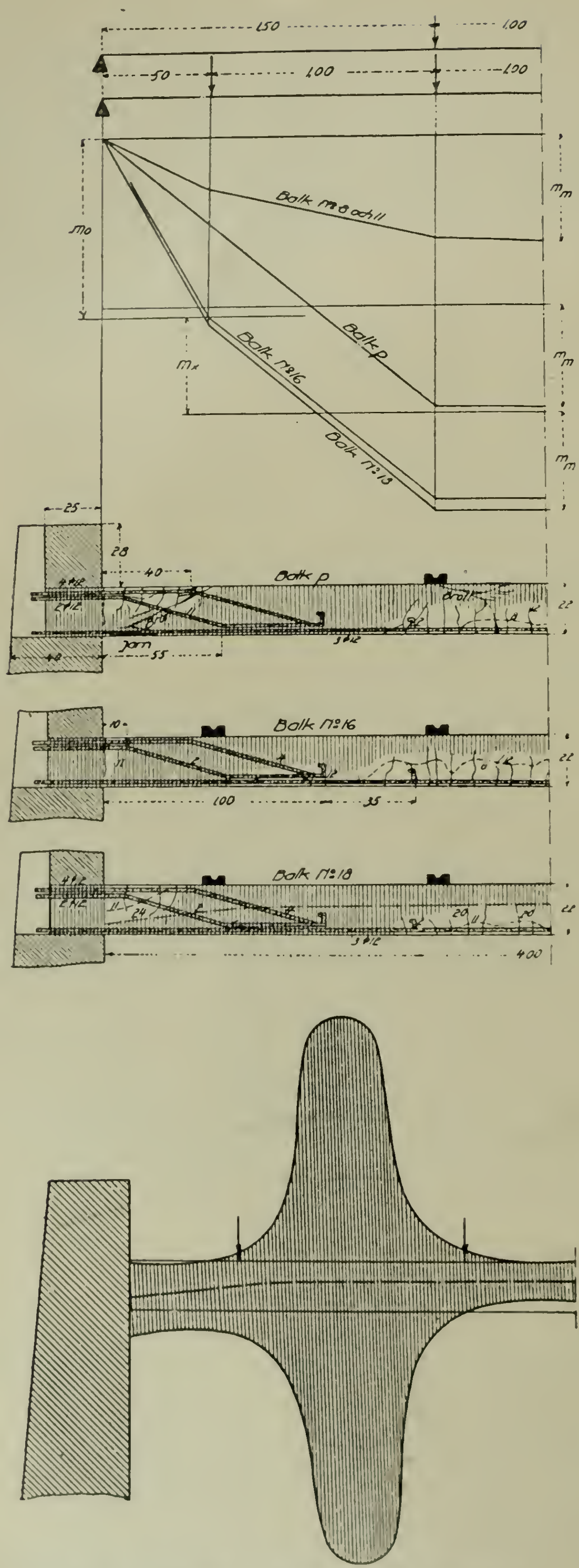


FIG. 9. DIAGRAMS OF BEAMS WITHOUT SKEW-ENDS.

and quickly diminish as the quality of the concrete improves. The effect of the hooping with concrete of the best quality is practically negligible. Tests published in *Beton und Eisen*, 1920, show that with a ½ per cent. hooping an increase in breaking strain of 132 per cent. was obtained, with an aggregate of 1918 lb. per sq. in., but this increase only showed 38 per cent. with a concrete of 3052 lb. per sq. in. Hence, with concrete of 4,200 lb. per sq. in. crushing strength the increase resulting from the use of hooping would be less than 10 per cent. which may, for practical purposes, be neglected. The use of a stronger hooping naturally makes it possible to further increase this difference, but a limit is soon reached in practice, so that the idea of providing large arch sections with hooping, and obtaining by these means a considerable increase of strength over and above the strength of best concrete is not worth consideration. Engineers have either to be satisfied with the high figures claimed for first-class concrete or—and this appears to be the more reliable way—to increase the resistance of ordinary concrete by means of hooping. Such hooping requires an easily compressible concrete, because its effect only comes into play as a consequence of the compression, i.e. by the lateral expansion of the compressed body. First-class concrete is brittle, and it is not very suitable for hooping. No one can rightly deny the possibility of manufacturing concrete of the homogeneity required in building operations, but this is always a difficult matter. Moreover, the brittleness of the material is a weighty reason for its refusal. These qualities are a disadvantage chiefly in cases where the structure has to withstand certain changes of form, for instance in house or factory construction, in mining work and in the erection of forts. It is, however, unavoidable in all cases of building construction, and in some it is helpful if the material adapts itself to a certain extent to taking up supplementary stresses.

The crown sections of the bridge in Treptow and of the Hindenburg bridge in Breslau in which wire hooped cores were used, were tested for crushing strength at the official testing institutes at Berlin and Dresden.

Columns of 16 in. diameter and 6 ft. 8 in. length were tested in Dresden in the year 1916. One of the columns, made of concrete which had a strength of 1554 lb. per sq. in. and without cast iron, showed cracks at 175 tons pressure, and reached a breaking load of 188 tons, corresponding to an increase of resistance of 66 per cent. The same column with 10 per cent. of cast iron showed fine cracks at 450 tons,

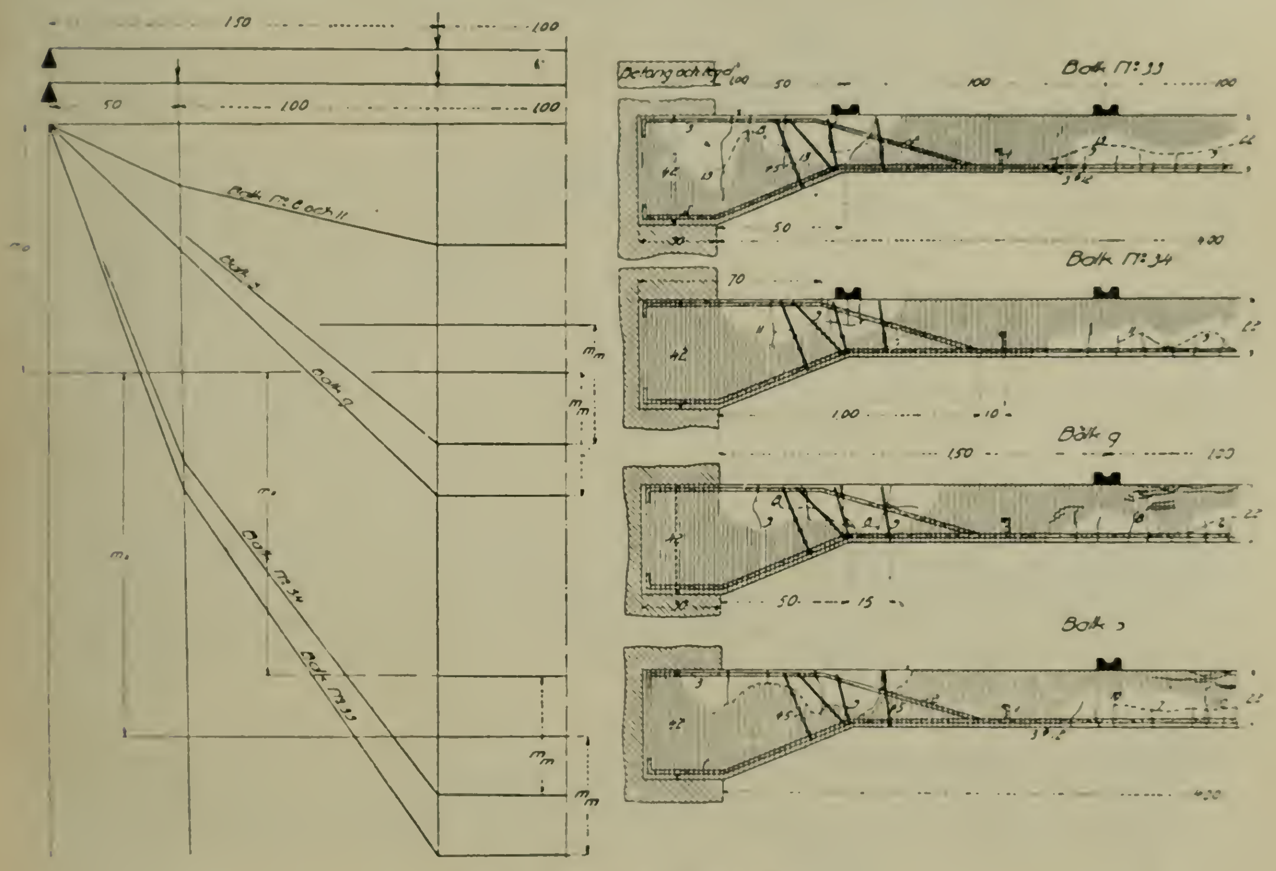


FIG. 10. BEAMS WITH SKEW-ENDS.

and reached a limit load of 960 tons, under which it did not collapse but only gave way gradually. This corresponds to a fivefold increase of carrying capacity, and a saving in deadweight of four times in comparison with a section reinforced with cast iron, and one with hooped concrete. The same results were shown by experiments with hooped stone core. Concrete of 3178 lb. per sq. in. attained by means of the hooping 4816 lb. per sq. in. or an increase of 38 per cent. till the limit of load of 180 tons was reached. By inserting a 12 per cent. stone section a load limit of 276 tons was obtained. Hence by means of the insertion of cores resisting high pressure it is possible to reduce the dimensions of the centre arch considerably, and to decrease its deadweight up to one quarter, at the same time retaining the strength of the total section and its security against collapse.

Of still greater importance for arch construction are the tests made with eccentric loads, which are comparatively rare. They enable the eccentric force to act centrally upon part of the core, even if the ellipse is exceeded through the eccentricity. A column with 2¾ in. eccentricity still showed a breaking load of 490 tons. The proportion of resistance to breaking load between a plainly hooped column and one with cores of high resistance remains the same and exceeds it by more than five times. Hence such pressure-cores are particularly suitable for eccentric forces, and make it possible to leave a wider margin for placing the outermost pressure lines, and is the reason why eccentric tests conducted with crown sections of various bridges give such excellent results.

When an arch reinforced in the centre with a cast iron core, built of a concrete of about 2,800 lb. per sq. in. with a core of cast iron of about 112,000 lb. per sq. in.

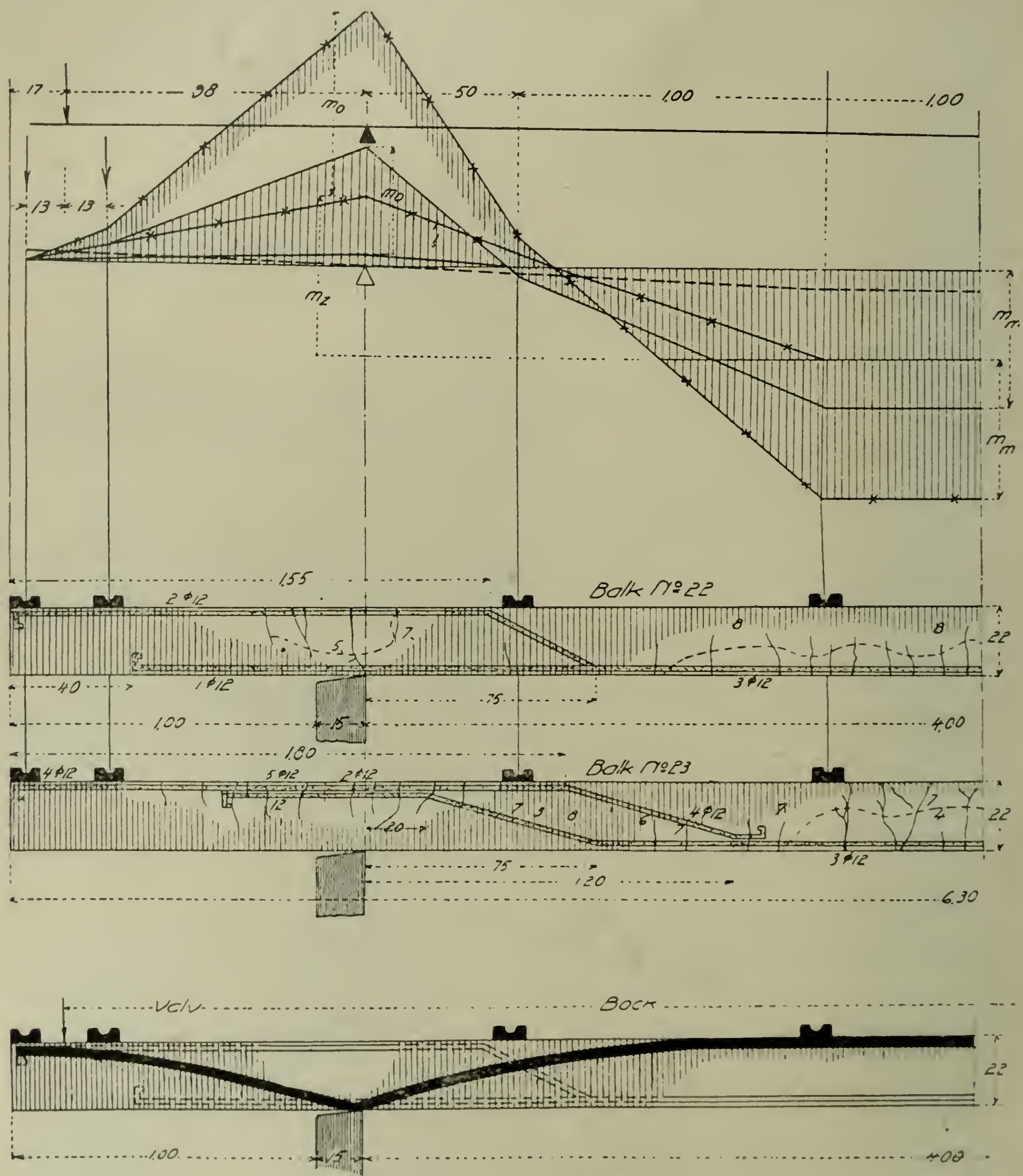


Fig. 11. Continuous Beams.

resistance to pressure, both held tightly together by means of the hooping, is considered the converting figure of 40 at the moment of rupture will result. This co-operation is arrived at in such a way that the modulus of elasticity first set in during the admissible loads in the proportion of 7·5 which then grows to 40 with the increasing load until the rupture. The whole range of temperature takes place exclusively within the limit of the admissible margin so that the figure 7·5 only comes into consideration for these increased temperature stresses, whereas for the safety of the building con truction the further effect of the cast iron which is five times more is at disposal. Hence the crown of comparatively little stiffness only releases small effects of temperature and an arch

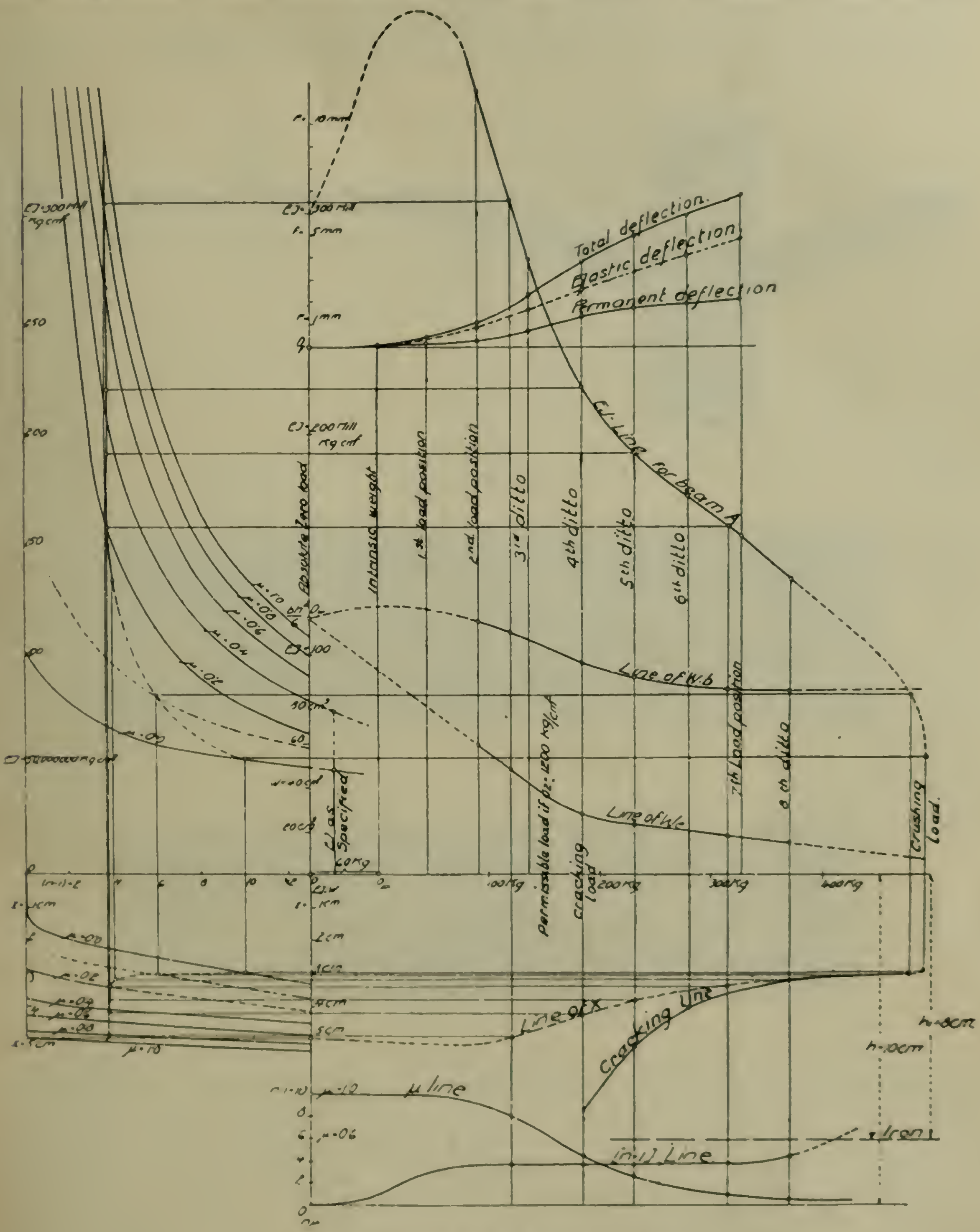


FIG. 12. COURSE OF E. I. IN CONTROL BEAM.

with an arrangement of moments of inertia which acts similarly to a crown hinge with regard to temperature.

This point of view permits an economic form of the carrying structure of the arch and has been adopted on various bridges and extended to the designs of the abutments, although nearly all of them consisted of pile foundations. This is explained by the fact that the constructions so far completed nearly always had to compete against girder systems and were to be carried in a soil where no one had ever intended to erect an arch. Those cases which appeared suitable for arches were taken up at the outset by Government or local men who relied upon the older proved methods without consideration of economy and technical advancement, and also upon the principle than an arch must be all the better the more ungainly it appears to the eye !

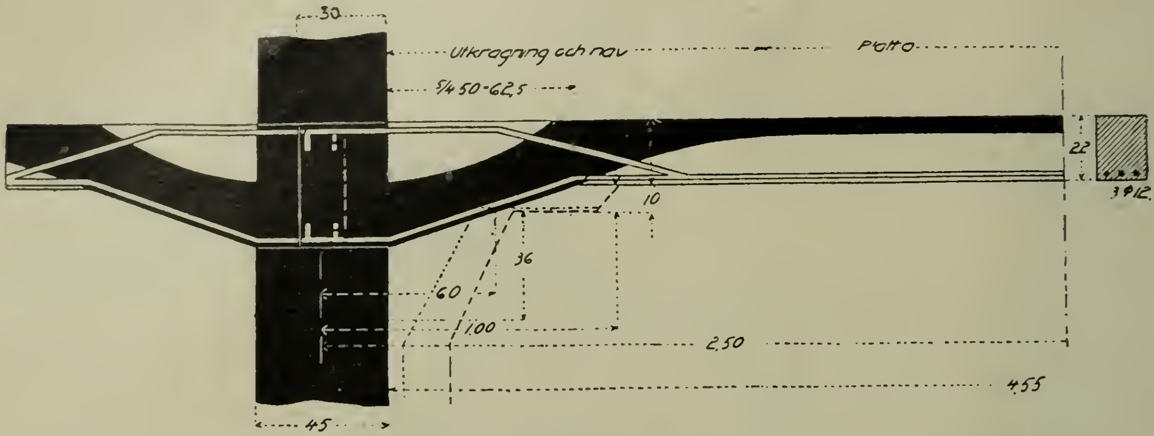


Fig. 13. Mushroom Flooring.

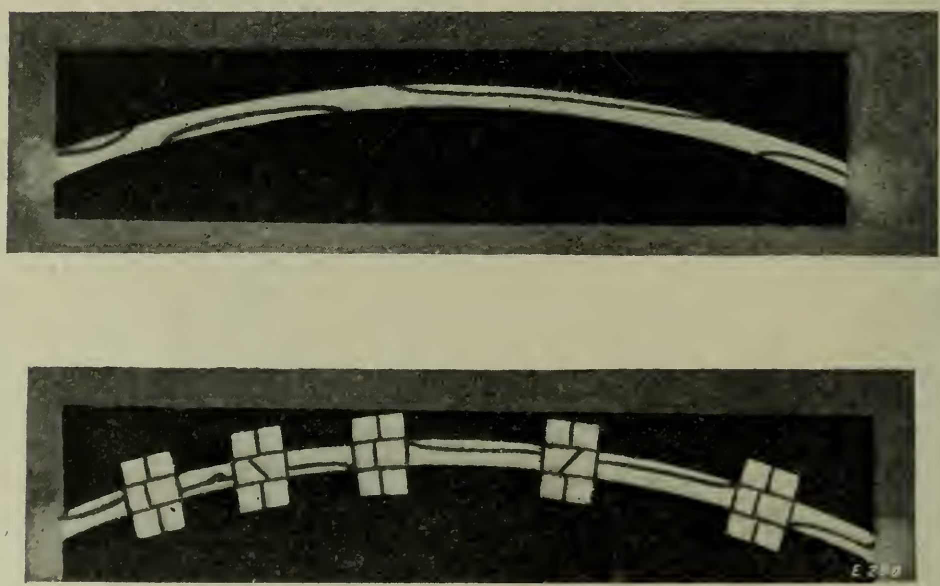


Fig. 14. Section and Plan of Glass Model Arch Bridge viewed by Polarised Light.

The proposed bridge over the Arstabay was the subject of an important decision : the jury for the competition for a bridge design with an arch of 600 ft. span has freely acknowledged the technical uniform solution proposed on the lines mentioned above and has said distinctly that this one made the best general impression of all the designs submitted. Unfortunately it was not given the first place in other respects as well. On the basis of the given span the largest of which so far is 407 ft. it was said that a span of 600 ft. would represent too big an advance. Yet Professor Linton's design has an arch of only 320 ft. resting upon two consoles of 120 ft. each. It is, therefore, nothing extraordinary as the consoles have the character of supplementary abutments. Professor Linton has, in fact, done everything to meet such doubts apart from the fact that they would have no weight even if they were correct. This example shows how difficult it is for technical progress to go ahead when even so excellent a body of engineers considers itself under obligation to hamper the further development of arch construction, for by such a decision the erection of arched bridges is naturally confined to cases where the necessary height for construction is available. The arch is the economic solution wherever there is sufficient height, because steel girders cannot utilise such heights. The development of arch construction demands, however, the use of wide span and flat arches so as to reduce the construction height.

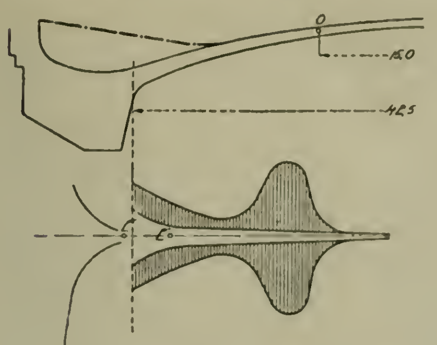


FIG. 15. EFFECT OF STRONGER SKEW-ENDS ON SCHWARTZENBERG BRIDGE.

The foregoing propositions may be summarised by the following :—

1. The construction should be made in the form of a two-hinged arch with temporary joints for the purpose of taking up displacements in the form after striking centres.

2. The finished structure, however, should represent a fixed arch with wide reaching consoles so as to reduce the clear span of the arch proper as much as possible.

3. The arch proper is to be constructed of such slender dimensions with the aid of a hooped section and a core of high resistance that a minimum of deadweight and the least effect of changes of temperature is attained.

4. The centring of the arch must have the character of a proper erection scaffolding.

5. The abutments must be economically constructed.

If all these suggestions are carefully considered, there is no doubt that, with the present prices of steel, massive arch bridges will be utilised more and more for wide spans, as they adapt themselves to economic conditions, to the further development of concrete arches.

With the high cost of steel bridges the chief obstacle is removed, and it is to be hoped that in future the demand for architectural beauty in bridge construction will once more make itself felt. The fine carrying line of the fixed arch with its slender crown corresponds to our æsthetic feeling and satisfies both architects and engineers alike by the clear expression of its purpose. Bridges with an arch and suspended roadway cannot attain this ideal so readily though it can be done in a satisfactory manner. It is further to be hoped that in the near future engineers may be freed from a thousand year old ban and will have an opportunity to construct arches which considerably exceed those erected by the ancient Romans.

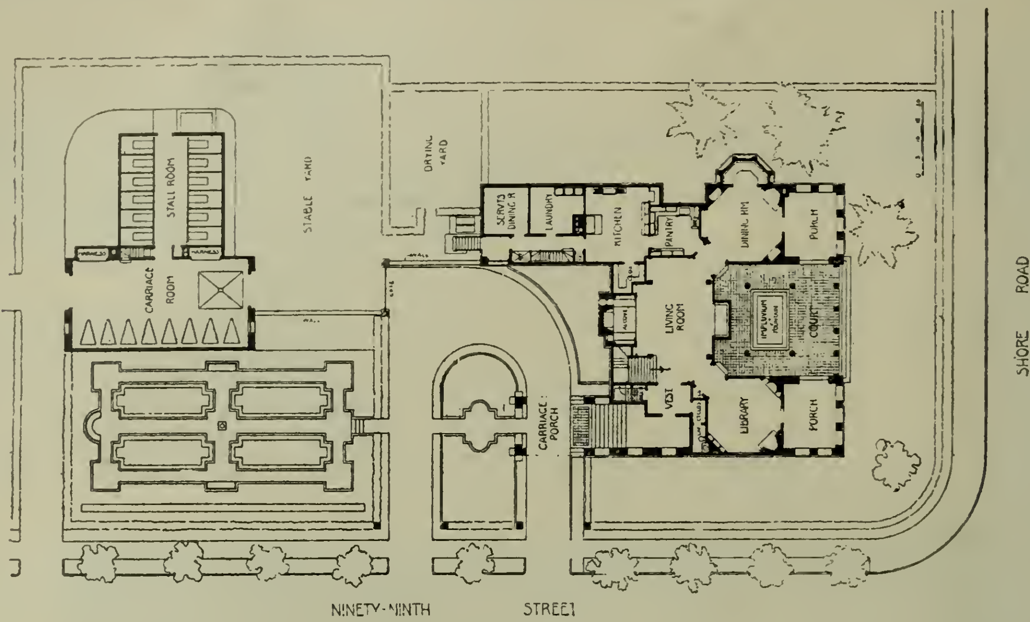
MEMORANDUM.

Reinforcing for 65-Ft. Cylinder Pier Placed as Unit.—In putting in the piers for Long Beach, Long Island bridge, which connects Wreck Lead with Long Beach, cylinders of an unusual length were used. The placing of the reinforcing steel became a problem, and this the contractor solved by building up the steel in squirrel-cage fashion, raising the whole by a derrick and lowering it into the cylinders. The squirrel cages were built upon circular templets made of double segmental layers of 2-in. lumber. To these were fastened the 1-in. vertical reinforcing bars, spaced on 6-in. centres. In one of the piers the cages attained a length of 65 ft., the templates being spaced about 8 ft. apart.

The circular reinforcement used was $\frac{5}{8}$-in. steel rods spaced on 2-ft. centres and to make the whole positive from breaking $\frac{5}{8}$-in. rods were fastened spirally at about 18-in. centres. When the cages had been made up they were hoisted into vertical position and lowered by a floating derrick with an 80-ft. boom. As the cages were lowered the templates were cut out.—*Engineering News Record.*

AMERICAN DOMESTIC ARCHITECTURE.

Concrete on expanded metal lathing has long been a favourite method of construction in America, and recent developments have produced a machine—the



Plan.

General View—House at Fort Hamilton.

cement gun—by means of which the concrete may be applied at a considerable saving of time and labour. The house at Fort Hamilton, New York, which we reproduce this month, is constructed in this manner. America is large enough to assimilate all European traditions and turn them to her own purpose, exhibiting thereby great skill, and this house is redolent of Italian influence. It is noticeable in the first place in the plan, which has a kind of peristylium, with a impluvium in the centre, after the manner of the Pompeian houses, and in its symmetrical arrangement about an axial line, and in the manner in which the octagonal library and dining-room connect by means of the spacious living room. The two porches confirm the presumption that the house is designed primarily as a summer resort. A successful elevation is obtained by means of a plain unbroken surface skilfully fenestrated. The unadorned arches of the porches, with their superimposed balconies, absolutely suffice in giving interest and suggest mystery to the masses which flank the court, and, although not visible in the illustration, it is easy to imagine the delightful effect produced by the glimpse of the sparkling fountain seen amidst the shadows between the gleam of the white Doric columns. The simple cornice, carried on brackets, is entirely in keeping, but an improvement to the design would have been effected by the addition of louvred shutters to the first floor windows. These would have had the effect of forming a kind of continuous frieze above the string course, and would have added to the suggestion—made by the ground floor treatment—of warmth and sunshine.

The house is interesting in that it shows, in conjunction with our previous examples, the scope of American domestic work; everything is turned to good account, and it is still possible to plan on the grand manner, while we are, for the most part, concerned with the aspect of the larder pram spaces, or whether the cottage shall have three or four bedrooms. It affords proof, too, if any is needed, of the suitability of the "stucco on wire lath" (to use the American vernacular) method of building for large work of first-rate importance.

MEMORANDUM.

Concrete Chimneys.—In a circular letter recently issued by the German Concrete Association the results of a *questionnaire* which had been answered by ten members of the Association and covered their experiences with concrete chimney stacks were treated in detail.

The principal question seems to have been the necessity of providing interior lining for chimneys subject to high temperatures. It was held by one firm that lining becomes necessary should the temperature exceed about 480° F., while another stated that in their experience unlined stacks had stood the test of about 570° F. Most of the firms declared, however, that lining may safely be dispensed with up to the latter temperature, while some of them stated that even higher temperatures had failed to produce detrimental effects. It would appear that the soot which precipitates on the inside surface of the stack acts as a protective agent against the action of heat and gases. One firm, with extended experience, say that concrete chimneys subject to higher temperatures than 660° F. should invariably be lined. Up to about 750° F. they hold that ordinary brickwork may be used, while for higher temperatures ranging up to 1112° F. the lower part of the stack, up to a height of about 30–45 ft. from the bottom, should be protected by refractory material. For still higher temperatures refractory lining should be used throughout. In case of acid gases likely to cause erosion, the lining must be acid-proof as well.

The letter concludes by calling attention to the fact that since 1910 a considerable number of concrete chimneys and smoke stacks have been erected in Germany, both by the monolithic method and by reinforced concrete block building, with heights ranging from 66 ft. to 394 ft.

THE MARRIOTT SYSTEM OF REINFORCED CONCRETE CONSTRUCTIONS FOR SIGNAL POSTS, POWER POLES, ETC.

(*Contributed.*)

The use of reinforced concrete on our railways has rapidly increased during the last two or three years, as any one who visited the Royal Show will know, for striking examples of signal posts, telegraph posts and power poles—to mention a few of the exhibits—were very prominent, not only from their towering dimensions but also from their perfect finish and neatness of design. Naturally it has taken considerable time to overcome the prejudice and uncertainty of this material, but we are convinced the latter objection is entirely overcome and the former is rapidly breaking down.

This state of affairs has been largely brought about by a few engineers who have

Fig. 1.

Fig. 2.

persistently studied the subject, knowing its vast possibilities from an economic point of view on account of its long life compared with other materials.

Some people are dubious as to the life of concrete, but where the work is properly carried out this fear is groundless. Mention might be made of the Dome of the Pantheon at Rome, constructed about A.D. 70.

One of the objections militating against its progress used to be its great weight as compared with wood, but, as will be seen from the photographs accompanying this article, structures in this material need be very little heavier than wood or steel strength for strength. It will be seen from the accompanying illustrations that the posts and

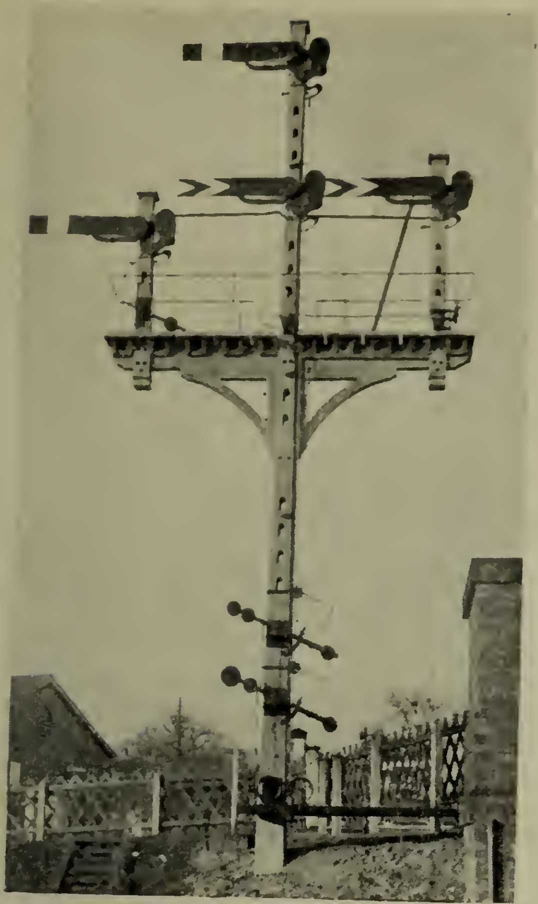


FIG. 3.

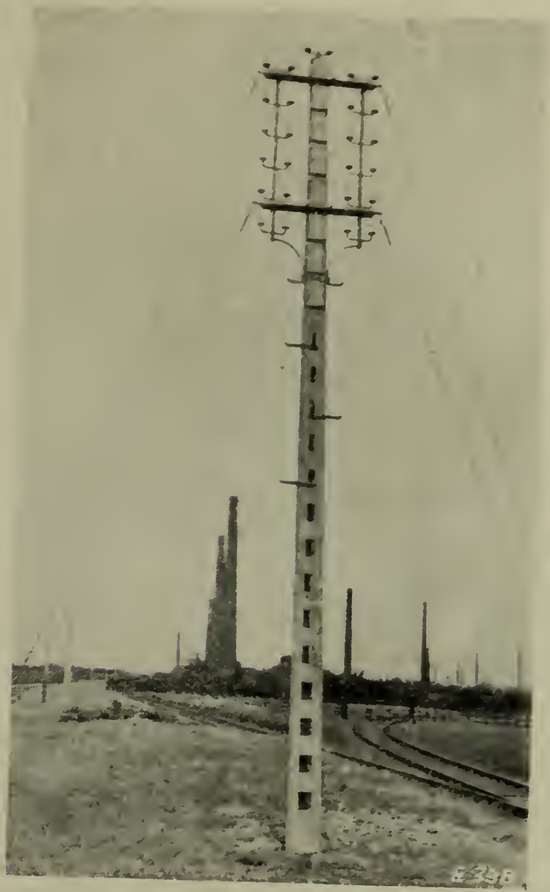


FIG. 4.

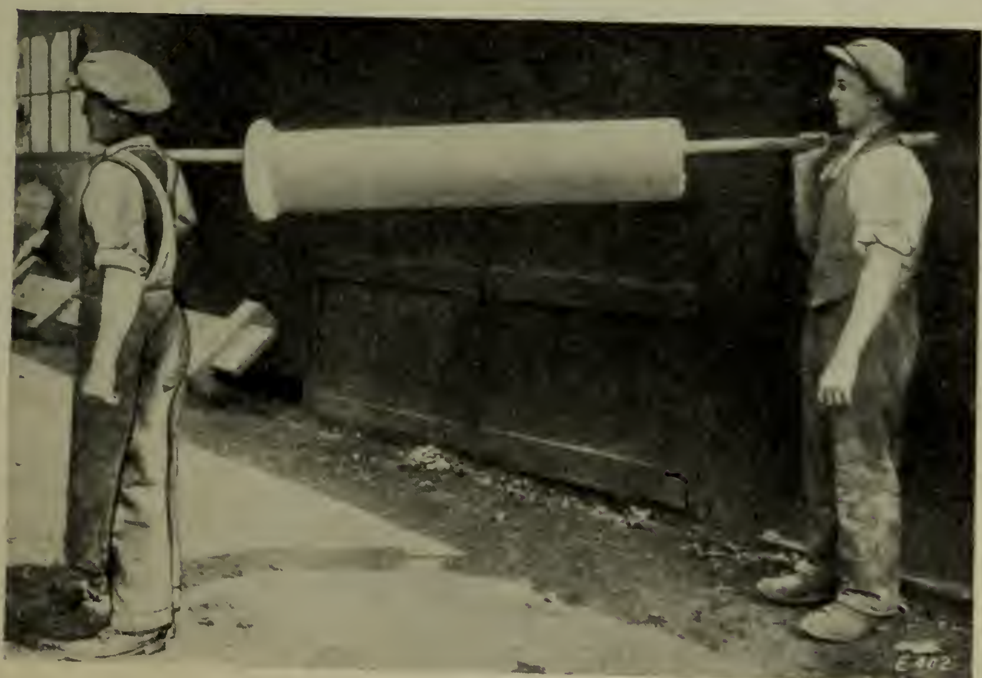


FIG. 5.

poles are cored out to lighten them, and we are informed that this in no-wise reduces their strength. The special design illustrated here is that of the Marriott Patent system of reinforcement.

These structures are also cored longitudinally, the walls of the concrete being only about 2 in. thick.

The large bracket signal post (*Fig.* 3) is believed by the designer to be one of the largest in the world at the present date ; it is entirely of concrete, except arm and

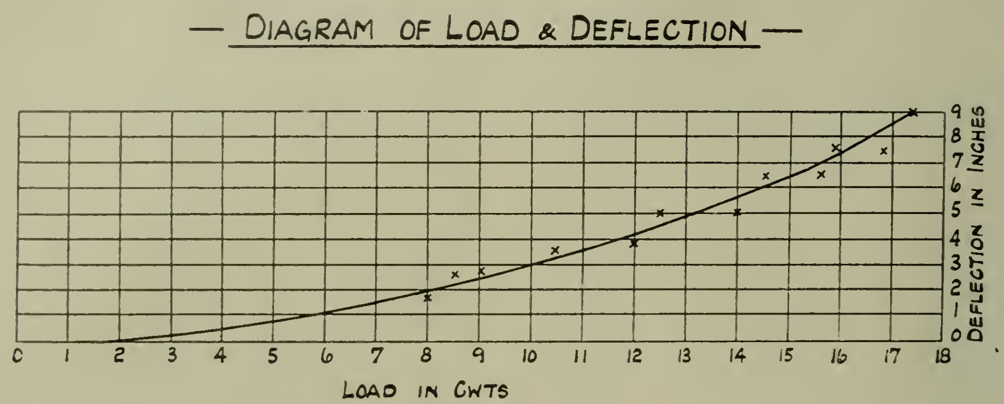


FIG. 6.

TEST OF MRC POLE (ROUND SECTION).

Date tested 11–8–20
Age . . . . . . 3 months

This pole was made in 4 ft. tubular lengths, assembled together. Length of pole over all, 24 ft. Tested in a horizontal position, 5 ft. being firmly fixed in base, load being applied at 18 in. from the top, leverage, 17 ft. 6 in.

Load lbs.	Load cwts.	Deflection inches.	*Remarks.*
952	$8\frac{1}{2}$	$2\frac{11}{16}$	First faint tension crack observed 4 ft. 9 in. above ground.
1,176	$10\frac{1}{2}$	$3\frac{1}{2}$	
1,400	$12\frac{1}{2}$	$5\frac{1}{8}$	First tension crack at joint noticed.
1,624	$14\frac{1}{2}$	$6\frac{5}{8}$	Tension cracks not yet serious ; pole still considered serviceable.
1,960	$17\frac{1}{2}$	9	Completely failed at or about ground line.
			No weakness whatever was apparent at any of the junctions of the tubular lengths.

Test load (breaking load) : 1,960 lbs.
Calculated safe load : 344 ,,

Factor of safety, safe load to breaking load $= \frac{1{,}960}{344} = 5{\cdot}7$.

Load at first faint crack : 952 lbs.

Factor of safety, safe load to first faint crack $= \frac{952}{344} = 2{\cdot}76$.

Maximum compressive stress on concrete at failure, 3,420 lbs./sq. in.
,, tensional ,, ,, steel ,, ,, 26 tons ,, ,,

Safe load calculated for 28 tons steel and 600 lbs. per sq. in. safe load on concrete in compression.

ladder. Only as recently as last summer, at the conference of the Institution of Civil Engineers, the engineer responsible for the paper on reinforced concrete stated that such signal posts appeared to be satisfactory.

Fig. 4 shows a line of telegraph poles carrying twenty-two wires ; the two end ones are square in cross section, the intermediate poles being triangular in cross section. It is possible to make poles equally as well and expeditiously to any desired shape and strength. The square pole is the most suitable for heavy strains and represents the design for power poles of the future, especially in foreign countries where the white ant is so destructive to wood and where storms also are very violent. Steel again is very expensive and needs regular painting to keep it from wasting by rust. To meet the needs of foreign countries where railways and roads are scarce, and transport consequently very difficult, poles may be made by this system in short lengths which can be carried by coolies (see *Fig.* 5).

Fig. 7.

Fig. 8.

These lengths are standardised and stocked so that poles can be quickly built up at the site to any length and strength required, either round or square. A round pole built up in this manner proved to be exceedingly strong as will be seen by the details of the test (see *Fig.* 6).

Fig. 7 shows a built-up pole erected.

Fig. 8 shows a light telephone pole of cruciform section which is very strong for its size.

Fig. 9 gives details of test of the cruciform pole, whilst *Figs.* 1 and 2 show the poles under test.

Fig. 10 shows a long range of concrete poles.

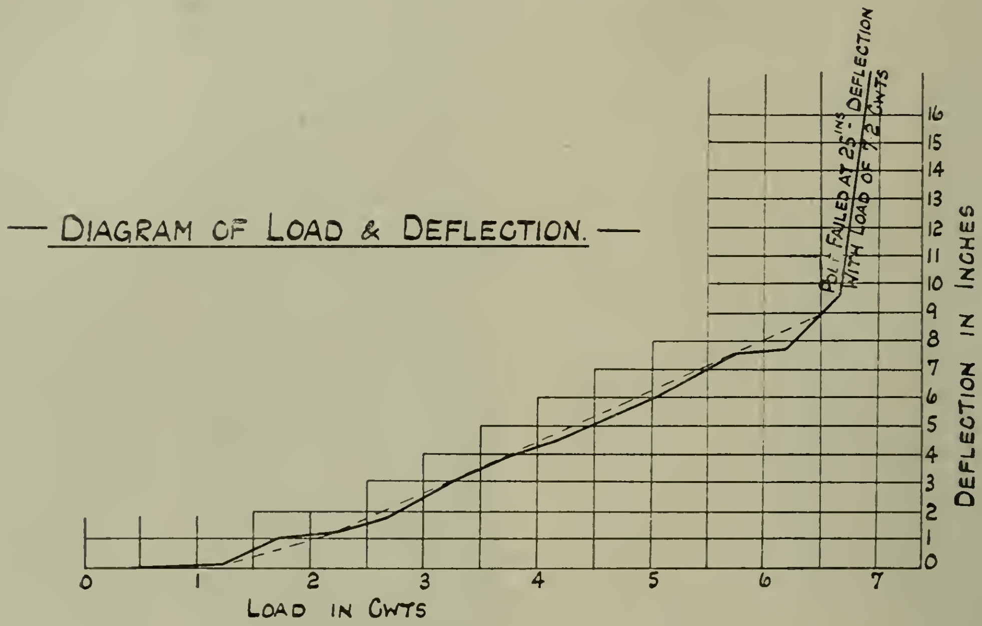


FIG. 9.

TEST OF MRC CRUCIFORM POLE.

Date tested . . 29–3–20.
Age . . . 1 year 4 months.

3 ft. 9 in. firmly fixed in the base and load applied $1\frac{1}{2}$ in. above top hole so that leverage was 15 ft. $8\frac{1}{2}$ in.

Load lbs.	Load cwts.	Deflection inches.	*Remarks.*
359	3·2	3	Cracks began to open.
583	5·2	$6\frac{3}{8}$	
695	6·2	$7\frac{3}{4}$	Cracks only moderate.
807	7·2	25	Pole failed under this load by concrete crushing at base. Tension rods practically undamaged and pole sprang back 9 ins. when load was removed.

Calculated safe load for same leverage = 134 lbs. (1)
Breaking load = 536 ,, (2)
Load at first crack = 359 ,, (3)

Factor of safety $\frac{(3)}{(1)} = \frac{359}{134} = 2{\cdot}68$

Load at failure = 807 ,, (4) 3,600 lbs./sq. in. on concrete
35 tons/sq. in. on steel

Factor of safety $\frac{(4)}{(1)} = \frac{807}{134} = 6$

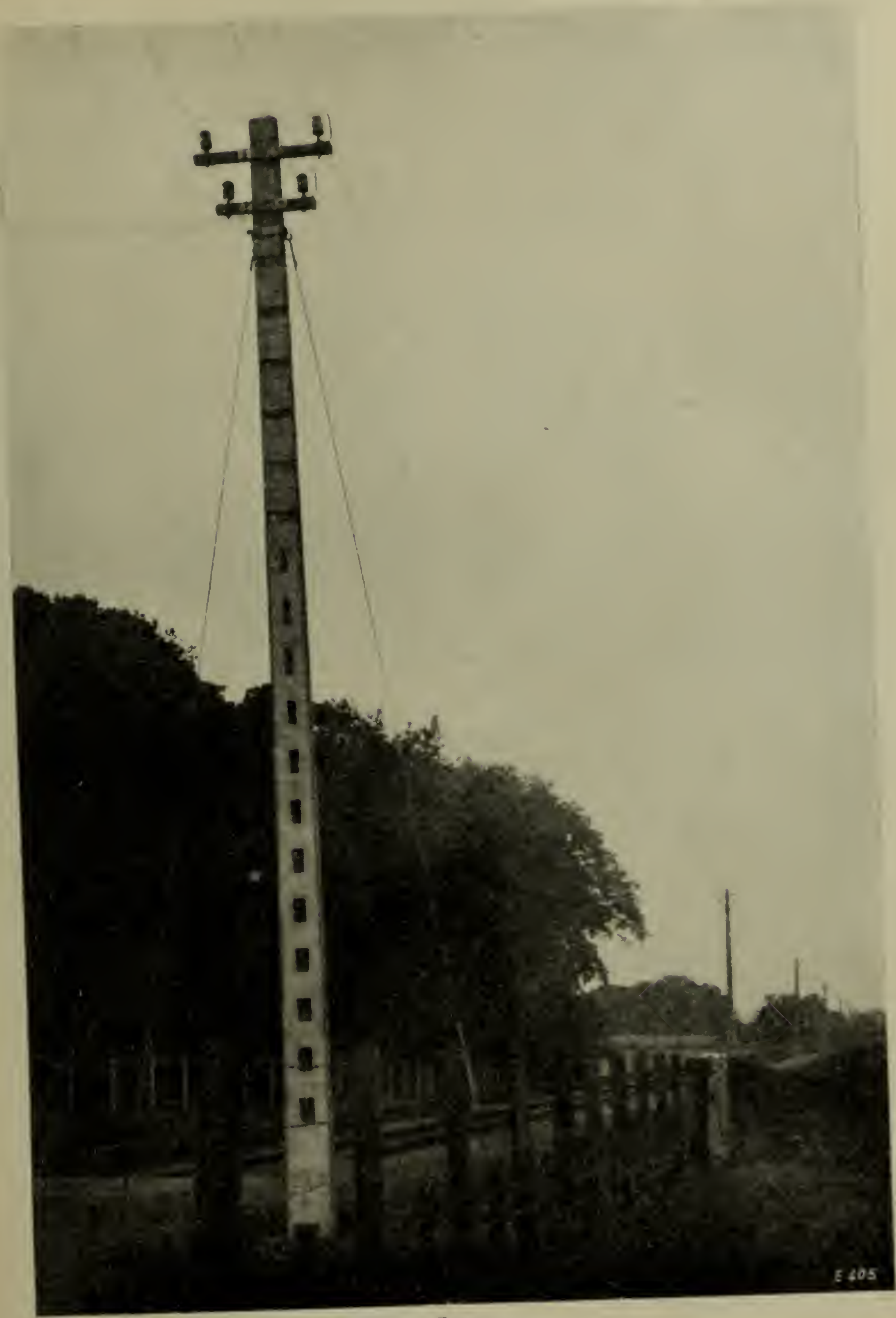


FIG. 10.

All the poles are calculated and designed for a minimum of weight and a maximum of strength, and can be made for any loading to any required factor of safety.

Special attention is given to the proper grading of materials and mixing of concrete, the aggregate being, when necessary, passed over a furnace to dry it and ensure proper mixing with the cement.

With power lines looming in the near future, these poles with their low maintenance cost, needing no painting, should have many possibilities. The transport problem may be said to be solved by the built-up pole, but when rail and road are available the entire pole can be easily brought to the site and erected.

The licensees for the Marriott constructions are the old firm of John Ellis & Sons, Leicester, and the Sales Agent is Mr. W. Jones, 154, Upper Thames Street, London.

MEMORANDUM.

Annual Dinner of the Concrete Institute at the Savoy Hotel, Thursday, February 2nd.—The Concrete Institute at their annual dinner this year introduced an innovation by extending the invitation to ladies, who attended in considerable numbers.

The function was a brilliant one, and amongst the distinguished guests present were The Right Hon. Sir Alfred Mond, Bart. (Minister of Health), The Rt. Hon. Lord Riddell and Lady Riddell, The Very Rev. W. R. Inge (Dean of St. Paul's) and Brig.-Gen. Sir Henry Maybury (Director of Roads, Ministry of Transport). Mr. E. Fiander Etchells presided.

In proposing the toast of His Majesty's Ministers, the President said that, in the Minister of Health they had one of the hardest worked Cabinet Ministers, whose duties covered such widely differing subjects as nursing, health, housing, worm and weed killers ; and it would be his duty to sign and approve the reinforced concrete regulations whenever they should be revised. Upon the Cabinet depended the destiny of the Empire. They therefore trusted that the decisions of the Cabinet would be wise and would consolidate the position of the Empire which had passed, and was passing, through troublous times.

Sir Alfred Mond, in reply, said that the office he had the honour of holding in 1916 as First Commissioner of Works brought him, perhaps, into closer touch with the subject in which they were all interested than the office he now held. In the Office of Works they had a trained expert to deal with concrete and reinforced concrete, and when a Government department has reached the pitch of employing an expert in any industry that industry had arrived. Referring to the national position to-day, Sir Alfred said this country stood as a firm rock in the middle of a quaking world. England was a building the Concrete Institute could well be proud of. It stood firm on its foundations, reinforced right through, with no weak trusses, no tendency to sag, no cracks developing in frosty weather, and no water to penetrate in a storm. It was tight, comfortable and strong, and the world looked to England to keep it so.

Lord Riddell proposed the toast of the Concrete Institute. In the course of his remarks he said he knew enough about concrete to know that it was a very tough subject, but until he read Mr. Etchells's Presidential Address he did not realise its extraordinary ramifications. Then followed a humorous analysis of the recent Presidential address and an appreciative reference to the work of the new secretary, Captain M. E. Kiddy. Continuing, Lord Riddell said he had had a good deal of experience of such organisations as the Concrete Institute, and he had for long been of the opinion that such bodies formed one of the most useful and admirable phases of the professional and industrial life of the country.

Referring to the remarks of Sir Alfred Mond, he said the fate of 45,000,000 people depended, not on governments, nor on the press, but on the resuscitation of foreign trade.

In responding, the President explained that the Concrete Institute was a scientific body which formed a common platform for engineers, architects, physicists and all those who had interests centred around the artistic side of concrete.

The toast of " The Guests " was proposed by Mr. J. Ernest Franck, F.R.I.B.A., to which Dean Inge and Sir Alfred Robbins suitably responded.

CEMENT NOTES.

By Our Special Contributor.

The Setting Time of Concrete.

COMPLAINT is occasionally made that the setting time of concrete does not bear any definite relation to the setting time of the cement contained in it, and comment on such a statement has hitherto been difficult because of the absence of any method of determining the setting time of concrete. This difficulty has now been removed by the invention of the "Flow-Table" which was designed primarily for the determination of the "flowability" or consistency of concrete. This apparatus consists of a table about 30 in. diameter mounted on a shaft which, by means of a cam on a horizontal crank shaft, is raised and allowed to drop freely a distance of ½ in. A mass of concrete moulded in the form of a truncated cone 4 in. bottom diameter, 2 in. top diameter and 2 in. high is placed on the table and jolted fifteen times by the method described. The bottom diameter of the mass is then measured, and its relation to the original diameter expresses the degree to which the concrete has flowed.

For determination of setting time, a series of truncated cones is moulded and jolted on the flow table at intervals, say of one hour or less, until the time arrives when the concrete does not spread or increase in diameter; the period between this time and the time of moulding is said to be the setting time of the concrete.

In some experiments by Watson Davis, reported to the American Society for Testing Materials, it is shown that for a 1 : 1½ : 3 concrete, a dry mix set in one and a half hours, a medium mix in three and a quarter hours, and a wet mix in five and three-quarter hours, the corresponding compressive strengths at twenty-four hours being 400 lb., 320 lb. and 185 lb. per sq. in. With a neat cement setting in four and a half hours (according to this apparatus) a 1 : 1½ : 3 concrete set in six hours and 1 : 3 : 6 concrete in seven hours.

It is suggested that this method of testing concrete may have a practical application in connection with the finishing or surfacing of concrete floors. It is well known that in granolithic floor work, the "finisher" goes over the surface with either a wood or steel float when the concrete has reached a certain consistency, steel floating requiring a stiffer concrete than wood floating and being capable of giving a smoother surface. But the period at which the necessary consistency is reached is indefinite, and it frequently happens that "finishers" are detained far beyond ordinary working hours in this connection, leading in some cases to indifferent workmanship. With the use of the flow table, it would be possible to fix a consistency at which "finishing" should be done to yield the best results, and it would also be possible to ascertain at what period this consistency would be reached.

The flow table also offers the opportunity of illustrating in a definite manner the effect of various aggregates upon the setting of concrete and further investigations in this direction would be useful.

Scientific Concrete Making.

THE value of cement with rapid hardening properties as distinguished from rapid setting properties has been illustrated in a striking manner in Switzerland, where it was required to remove the shuttering of some concrete arches of 118 ft. span within a few days of pouring the concrete instead of waiting for the usually stipulated period of forty days. By using cement which developed in ten days, the strength specified for the twenty-eight days period, it was found possible to remove the shuttering in ten to fifteen days, and there was accordingly considerable economy in timbering. In addition to the selection of special cement, careful attention was paid to the grading of the aggregate and the proportioning of the concrete, and, in fact, the preparation of the concrete was the subject of such scientific manipulation that nothing was left to chance. By this means, the strength of the concrete was considerably above that allowed for in the ordinary calculations, and the factor of safety was increased. This procedure adds little, if anything, to the cost of the concrete, and if its value could be realised there are great possibilities of economy, not only in timbering, but in reducing the dimensions of concrete work.

SOME EXTRACTS FROM THE FOREIGN PRESS.

COLOURS FOR CEMENT ARTICLES.

The production of coloured articles in cement mortar or concrete has always been somewhat unsatisfactory, and many façades which had a pleasing appearance when new have rapidly deteriorated and become unsightly. This applies especially to concrete tiles.

Reds.—The best red colours are produced by red bole, a natural oxide of iron whose tint has been developed by levigation and calcination. It is largely used as the basis of red oxide paints.

Several varieties of iron oxide are available, they vary considerably in composition, according to the amount of combined water present. The colour does not appear to be directly related to the chemical composition, but rather to the size and density of the particles.

One of the best forms is a by-product in the manufacture of sulphuric acid from calcined pyrites, but for use with cement it should be free from sulphurous acid, which is a common cause of scum and discoloration.

Yellows.—Ochre is the chief material used for the production of a yellow colour in cement work. It is a weathering product of ferruginous felspar and of very variable composition. It is usually kept for several years in the open, then ground and levigated so as to separate coarse impurities. Umber is a darker colour, but in many respects similar to ochre. Both ochre and umber reduce the strength of the cement mortar or concrete.

Zinc yellow (zinc chromate) is sometimes used as a yellow pigment, but its price is generally too high for its extensive use in concrete or cement work.

Blacks.—There are two chief sources of black pigment suitable for use with cement, namely manganese black and carbon black. Manganese blacks consist chiefly of manganese dioxide, whilst carbon blacks consist of slate, black shale or some form of soot, such as lamp black.

Ground coke is also largely used as a black pigment. All these materials must be particularly finely ground. Usually manganese black is more serviceable than carbon black, but is more costly.

Greens and Blues are made from ultramarine with some other pigment, such as chromium oxide, lime green or yellow ochre, to give the required shade. Contrary to all other colours, ultramarine increases the strength of the cement on account of the free (colloidal) silica and aluminium present which gives it hydraulic properties.

The best green pigment for cement mortar is chromium oxide prepared from a mixture of potassium bichromate and sulphur, it should be bought as its preparation is difficult.

Lime green is a magnesium alumino silicate (augite) containing some iron and of a very variable composition. Most green cement mortars or concrete fade on account of the oxidation of the iron present.—*Zement.*

APPLYING CEMENT MORTAR UNDER PRESSURE.

The application of cement mortar under pressure is effected in two ways, as—

(*a*) A hole is bored into the material to be impregnated, and a slurry of cement mortar is pumped through the hole under pressure until the requisite quantity has been applied.

(*b*) The cement mortar is sprayed on to the surface, sufficient force being obtained by means of pressure applied to the slurry, as in a cement gun. More recently it has been found better to use a dry mixture of cement and aggregate and to apply water under pressure to the surface to be covered.

The chief difficulty in applying a liquid mortar lies in its tendency to become unmixed, whilst if a dry material is projected through a long hose by means of a stream of water, a considerable amount of setting may occur, and the hose may gradually become choked. Imperfect mixing of the solid and water may cause further difficulties.

In the " Tector " process, the dry materials are mixed and moistened so as to have the consistency of garden soil, that is, with one third to one half to the normal amount of water. The remainder of the water is applied at the nozzle of the machine but has only a pressure of about 7 lb. per square inch, and so penetrates the moist mass quite readily. The hose pipe is never quite full of material, but has a current of air passing through it which breaks up the particles and facilitates the use of 100 yards of hose and enables chimneys and great lengths of tunnels to be worked without difficulty.

The advantages of applying concrete under pressure are :—

1. The great density of the coat or lining produced.

Coating a Chimney 120 ft. High at the Central Hotel, Berlin.

Rendering the Tunnel under the River Spree, Berlin, Waterproof.

2. Its resistance to water and its strength being much greater than stamped concrete. Slabs of ¼ in. when made by this process are completely impermeable to water under a pressure of 60 lb. per sq. in. (tests at higher pressures have not been tried).

3. The materials unite more firmly to old concrete and other materials than is the case with concrete applied by hand. When first concrete touches the old surface much of the coarse concrete falls off, leaving a film of cement mortar which rapidly fills all the cracks and irregularities in the surface to be treated, and adheres with extraordinary tenacity. As soon as the film has been formed the further concrete adheres fully to it, and produces a uniform coating of great adhesiveness.

4. Whereas with tamped concrete each layer is a source of weakness, when pres-

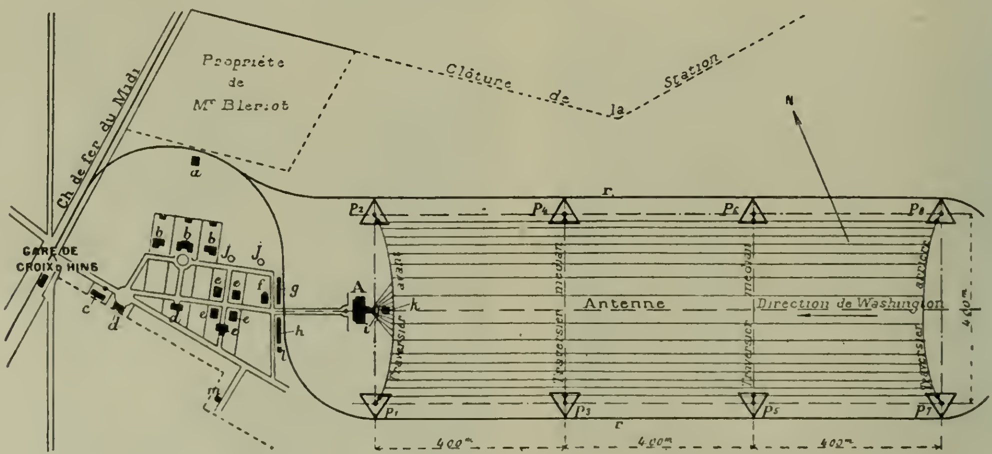
sure is used no difference in strength occurs at the junction of the various coatings, nor can any junction be seen.

Some engineers have feared that concrete applied under pressure would spall readily, but this does not occur to any greater extent than when concrete is applied in any other manner. Under certain adverse conditions spalling will occur under any circumstances, but whilst precise numbers cannot be quoted, it seems certain that concrete applied under pressure is less likely to spall than ordinary concrete.—Abstract from a paper read before the Association of Architects and Engineers of Munich, August, 1921.

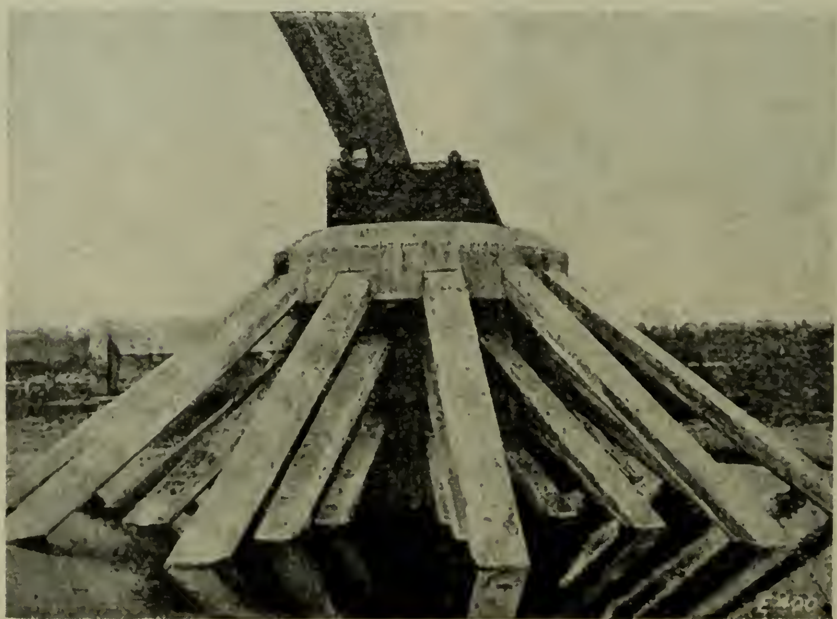
THE USE OF CONCRETE IN WIRELESS WORK.

The wireless telegraph station at Croix-de-Hins, near Bordeaux, contains some interesting examples of the usefulness of reinforced concrete, particularly for the construction of the pylons and foundations on a site which would, ordinarily, be regarded as incapable of supporting them.

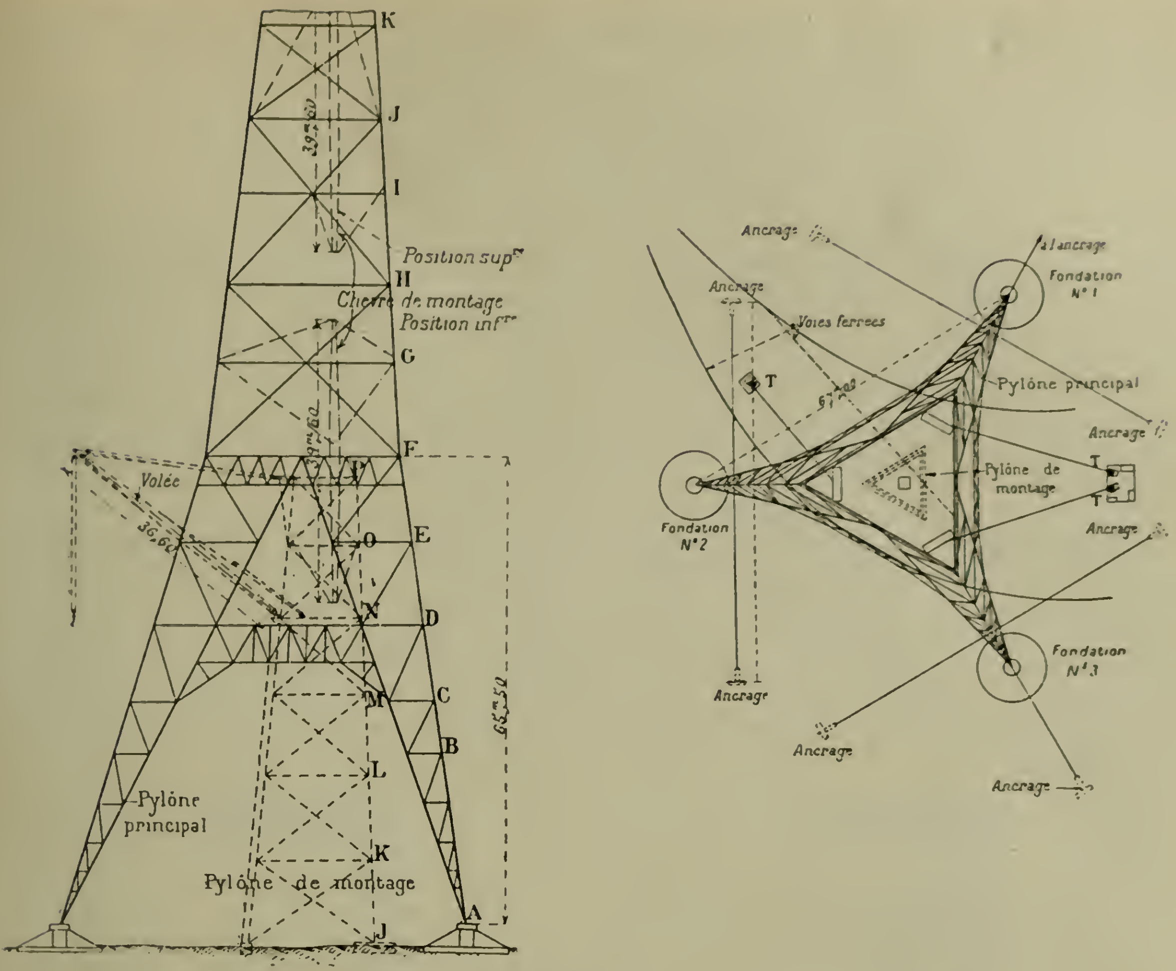
As the ground was very wet, and its load-bearing capacity very uncertain, the principal pylons were built on a series of inclined piles of reinforced concrete, these piles being arranged to form a truncated cone, 12 ft. high, and 43 ft. in diameter at the base, as shown in *Fig.* 2. Each cone was anchored to other concrete piles below ground level, and not shown in the illustration.



Plan of Site.



Base Cone of Pylons.



PART ELEVATION AND PLAN OF PYLON.

ASSEMBLING A PYLON.

BASE OF TOWER.

Each pylon is triangular in plan, 834 ft. high, and divided into twenty-four stages, the steel weighing about 560 tons, so that for the eight pylons at the station, about 4,500 tons of steel have been employed, and not less than 197,000 rivets.

The eight pylons are 444 yards apart, in two rows, a railway being used to bring the various portions into the required positions, from which they could be raised by means of steam- or electrically-operated cranes, mounted on a temporary staging in the centre of each pylon as shown in *Figs.* 3 and 4.

The principal building containing the electric dynamos, alternators, and other appliances, consists of three large halls, side by side, with an area of 188 ft. by 50 ft. Behind this building is a tower, by means of which the wires from the aerial enter the building. This tower is rectangular in plan, with four bays; it is surmounted by a dome, the top of which is 80 ft. above ground-level. The tower, even allowing for the effect of wind-pressure, weighs less than 100 tons; it is supported by four pillars by means of a series of elliptic vaults, and by two beams, all of reinforced concrete. The whole of the concrete work was executed by the Société des Grands Travaux of Marseilles.—*Le Genie Civil,* 1921, 517-524.

CLOSED STOVES OF CONCRETE.

What appears to be a novel use of concrete, is in the construction of the closed stoves which are found all over Central Europe. These stoves are usually made of glazed fireclay by A. Kern, of Frankfurt-a-Main, who has recently patented (Ger. Pat. 730,790) the construction of stoves of reinforced concrete.

Fig. 1 shows one of these ovens with three small chambers in which food can be kept warm. *Fig.* 2 has only two such chambers, but, in addition, there is a water heater of about 10 gallons capacity. Both these stoves are 6 ft. high, 16 in. wide, and 22 in. deep.

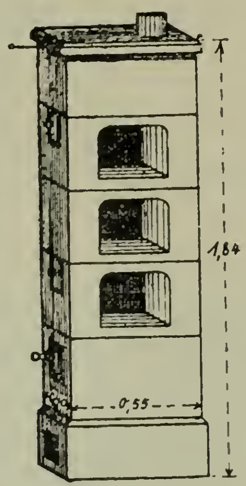


FIG. 1.

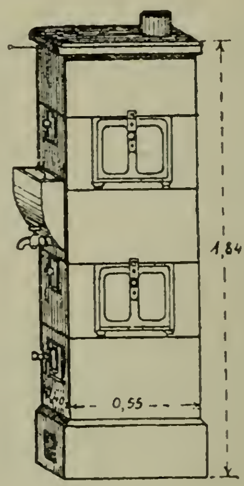


FIG. 2.

Each stove consists of five or six separate pieces, and the cover. Each piece is moulded separately. When assembled, the stove consists of an ashpit, a grate and combustion chamber, the heating tubes forming the first hot chamber, the water-tank or second hot chamber, the third or upper hot chamber, a top section, and the cover.

These stoves appear to be equally as efficient as those made of stoneware, but cost half the money. The heat-resistance of the concrete has been fully proved in the 1½ years during which some of these stoves have been in regular use. It is, however, essential that the stoves should be dried very slowly and with a gentle heat; afterwards they may be heated and cooled as rapidly as desired.—*Beton und Eisen.*

AMMONIUM COMPOUNDS AND CONCRETE.

A series of investigations by Dr. R. Grun have shown that ammonium compounds have a harmful effect on concrete, especially those which form soluble potassium salts. The sulphate-chloride or other acid radicle in the ammonium salt combines with lime in the concrete, liberating ammonia. In their corrosive effects such salts behave like acids. From the results of his experiments Dr. Grun considers that concrete should be protected from ammonia salts just as much as from acids.—*Zement.*

NEW BOOKS
AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

An Investigation of the Fatigue of Metals. By H. F. Moore and J. B. Kommers.
Bulletin No. 124. University of Illinois.

This excellent bulletin outlines the experimental work from which the following " conclusions " are derived :—

(1) For metals tested under reversed stress there was observed a well-defined critical stress at which the relation between unit stress and the number of reversals necessary to cause failure changed markedly. Below this critical stress the metals withstood 100,000,000 reversals of stress, and, so far as can be predicted from test results, would have withstood an indefinite number of such reversals. The name " endurance limit " has been given to this critical stress.

(2) In the reconnaissance tests made in the field of ferrous metals no simple relation was found between the endurance limit and the " elastic limit," however determined. The ultimate tensile strength seemed to be a better index of the endurance limit under reversed stress than was the elastic limit. The Brinell hardness test seemed to furnish a still better index of the endurance limit. The reason why the Brinell test, and, to a less degree, the ultimate tensile strength, seem to be better indices of the endurance limit than the elastic limit is not clear, and this result should be regarded as tentative. Elastic limits determined from compression tests and torsion tests gave no better index than did those from tension tests.

(3) The single-blow impact tests (Charpy tests) and the repeated-impact tests did not furnish a reliable index for the endurance limit under reversed stress of the ferrous metals tested.

(4) Accelerated or short-time tests of metals under repeated stress, using high stresses and consequent small numbers of repetitions to cause failure, are not reliable as indices of the ability of metal to withstand millions of repetitions of low stress.

(5) The endurance limit for the ferrous metals tested could be predicted with a good degree of accuracy by the measurement of rise of temperature under reversed stress applied for a few minutes. This relation is explicable in view of the intercrystalline and intracrystalline slippage under repeated stress shown by the microscope. It is believed that this test, which is a development of a test proposed by Mr. C. E. Stromeyer, can be developed into a reliable commercial test of ferrous metals under repeated stress. Its applicability to non-ferrous metals has not been investigated.

(6) Abrupt changes of outline of specimens subjected to repeated stress greatly lowered their resistance. Cracks, nicks, and grooves caused in machine parts by wear, by accidental blows, by accidental heavy overload, or by improper heat treatment may cause such abrupt change of outline. Shoulders with short-radius fillets are a marked source of weakness.

(7) Poor surface finish on specimens subjected to reversed stress was found to be a source of weakness. This weakness may be explained by the formation of cracks due to localised stress at the bottom of the scratches or tool marks.

(8) Stress above the endurance limit, due to either a heavy overload applied a few times, or a light overload applied some thousands of times, was found to reduce somewhat the endurance limit of the two ferrous metals tested.

(9) In none of the ferrous metals tested did the endurance limit under completely reversed stress fall below 36 per cent. of the ultimate tensile strength ; for only one metal did it fall below 40 per cent., while for several metals it was more than 50 per cent. However, these metals were to a high degree free from inclusions or other internal defects ; the specimens had no abrupt changes of outline, and had a good surface finish.

(10) It is well known that subjecting steel to a stress beyond the yield point raises the static elastic tensile strength to a marked degree. The effect is less marked on the endurance limit, although some increase was observed for 0·18 carbon steel with the surface polished

after being stretched well beyond the yield point. Annealing of commercial cold-drawn screw stock was found to lower its endurance limit somewhat less than it did its static elastic strength.

(11) The test results herein reported indicate the effectiveness of proper heat treatment in raising the endurance limit of the ferrous metals tested. Here again it should be noted that an increase in static elastic strength due to heat treatment is not a reliable index of increase of endurance limit under reversed stress.

(12) The phenomenon known as "fatigue" of metals under repeated stress might better be called the "progressive failure" of metals. The most probable explanation seems to be that such failure is a progressive spread of microscopic fractures. A nucleus for damage may be a very small area of high, localised stress, due to a groove, a scratch, or a crack; in other cases failure may be due to internal inclusions or irregularities of structure; it may be due to internal stress remaining after heat treatment; it may be due to a grain or group of grains unfavourably placed to resist stress; or failure may begin in the weaker grains of a metal whose structure consists of two or more kinds of grains; or it may, of course, begin in any portion of the metal which, by accidental overload or otherwise, is stressed to the yield point. O. F.

Applied Calculus. By F. F. P. Bisacre, M.A., B.Sc., A.M.Inst.C.E.
446 pp. Price 10s. 6*d*. net. London: Blackie & Son, Ltd.

So many text-books have been written upon the calculus that one is constantly wondering whether any of the newer ones can possibly justify their appearance; after reading through Mr. Bisacre's book the reviewer is quite convinced that here at least is one that can.

One of the reasons why so many writers have (literally) entered the lists is that the subject is one of remarkable elusiveness; many of us wade through it for a long time before we can view it with any perspective and most students never get to that stage at all, and it is the hope of bringing some, if not all, of these wandering sheep into the fold that tempts so many writers to present books in which the points which seem to them to present the difficulty are dealt with in some other way.

Mr. Bisacre has struck off on what to the writer is a new line; he gives us portraits of great mathematicians and physicists, and short, but aptly chosen biographical notes about them. He also cleverly puts a sugar coating on his pill, and his first two chapters open like a "book" with quotations from Marcus Aurelius and Carlyle and a story about Kepler and wine barrels, and we positively want to go on reading. If anybody had said that they enjoyed the opening chapters of the calculus books of thirty years ago he would have been correctly dubbed a freak.

When we come to the pill itself we find it wholesome and likely to do us lasting good. The book maintains a lucid and crisp style and its printing and illustrations are above the relatively high standard of the average British text-book.

After dealing with the usual aspects of the differential and integral calculus we have three chapters dealing with "some problems in Electricity and Magnetism, Chemical Dynamics and Thermodynamics."

The applications of the calculus to the problems which are of special interest to the structural engineer do not appear to be given extended treatment, but for those students who wish to obtain a good general insight into the foundations of the mathematical aspects of the mechanical science no better book could be recommended.

E. S. A.

The Metric System for Engineers. By C. B. Clapham, B.Sc. Eng. (Lond.).
181 pp. Demy 8vo. 12*s*. 6*d*. net. London: Chapman & Hall, Ltd.

Mr. Clapham has already proved in his *Arithmetic for Engineers* that he is a clear and careful writer of engineering text-books, and the present volume possesses the characteristics of good presentation and clear illustration that distinguished his other book in the "Directly Useful" series of text-books that the late Wilfrid J. Lineham founded.

One's only misgiving on studying the book is that, particularly in these impecunious days, there are not many engineers whose requirements as to the metric systems are not sufficiently met by the tables already to be found in the engineering pocket-books, nor students who do not find one chapter in a general text-book enough to satisfy their needs.

A word must be put in for the very excellent loose conversion charts which are issued with the book, and which are in a form which to the writer is novel, although obviously the best form.

The publishers and author are to be congratulated upon a book in which the printing, paper, illustrations and text are of a very high standard.

E. S. A.

Manufacture of Portland Cement. By Arthur C. Davis, M.Inst.C.E.I., M.I.Mech.E., F.C.S., etc.
Dublin. John Falconer, 53, Upper Sackville Street. 25s. net.

This work has now reached its third edition, the contents having been re-written and brought up to date by the addition of new matter which describes the latest developments in the manufacture of Portland cement, and the most recent methods of testing.

In order that a book may exercise its fullest appeal, the reader must have the utmost confidence in the author and his knowledge of the subject. In writing this work Mr. Davis brings to bear his intimate practical acquaintance with, and thorough mastery of, every detail of cement manufacture, and his scientific training enables him to weigh impartially the various theories upon the subject which have from time to time been propounded.

Since the last edition was published, research work has been constantly going on, and although it cannot be said that finality has been reached in our knowledge with regard to the properties and chemical constituents of this product, or of the chemical and physical changes which take place during hydration and setting, yet a steady advance has been made in this direction, and the latest conclusions on the theoretical aspect of Portland cement are set forth very completely in the present edition; and in "The Mechanism of Setting and Hardening," which is a new chapter, all that is really known about this obscure subject is very lucidly summarised.

As the Portland cement of to-day is entirely a scientific product, and no longer the outcome of rule-of-thumb methods, it might have been expected that, in a work of this kind, the author would devote considerable attention to this branch of the subject. How thoroughly Mr. Davis has done this, both with regard to manufacture and testing, will be seen at once by noting the headings of the chapters and the summary of their contents.

We should recommend the reader to study carefully the chapter on "Sampling, Testing and Uses" in which the author deals at considerable length with faulty methods of testing and with the many ways in which a thoroughly sound and reliable cement may be rendered unsatisfactory in use through bad practice. To this chapter has been added useful information concerning aggregates, methods by which concrete work can be carried on in cold weather, the question of waterproofing and the suitability of concrete for the storage of certain mineral oils.

This book is a most valuable contribution to the literature of Portland cement, and may be regarded as a standard work. It is of interest to the cement user since it provides him with that knowledge which will inspire confidence in the material; it is of value to the cement manufacturer in that it sets a high standard of efficiency and offers many valuable suggestions as to how this standard may be attained; and useful to the chemist since it points to a branch of Applied Science in which there is yet considerable scope for research.

The volume, which is well produced and copiously illustrated, should be in the hands of every engineer, contractor and cement maker, and of all others who are interested in cement and concrete.

MEMORANDUM.

Old London Bridge.—The Concrete Institute has appointed a special Committee in support of the efforts made by other societies for the preservation of the recently-discovered arch of Old London Bridge. Mr. W. J. H. Leverton has been elected Chairman, and will act as connecting link with the London Society, of which body he is a member of council. A public meeting is shortly to be held to ascertain what steps should be taken to ensure the preservation of this relic.

CORRESPONDENCE.

Under this heading we invite correspondence.

A correspondent writing from Buenos Aires sends us the following particulars regarding concrete blocks in Patagonia :—

Concrete Blocks.

The concrete block machine is apparently holding its own in several parts of the world. Noticing the campaign in your periodical in favour of this system of building construction in the British Isles, I thought it might interest you to know that even in Patagonia the block machine is gaining ground.

In the coast towns the big exporting and importing firms are having their warehouses constructed with concrete hollow blocks, gradually suppressing the galvanised iron corrugated sheets that have been in use for building, etc., in the past.

In the town of Santa Cruz, once the capital of Patagonia, brick houses can be counted on five fingers (1918).

Two warehouses and stores have lately been erected in Santa Cruz and two more in Puerto Reseado with concrete blocks.

Adobe bricks are not good owing to the climate, and kiln bricks are worth approximately £5 per thousand at the kiln and extra for transport. Railroads are non-existent.

View of Finished Buildings Armour & Co., Santa Cruz.

The big packing house of Chicago, Armour & Co., have just had constructed by the contractors, Messrs. Scott & Hume, a factory for the killing and preparing for shipment of 5,000 sheep per day.

This plant is situated at the fork of the Rio Chico and Rio Santa Cruz, at Beagle Point, so named by Captain Fitz-Roy after his ship H.M.S. *Beagle*, which took Darwin on his voyage of exploration. The town is 56 km. away, and the factory is about 2,000 km. from Buenos Aires.

Although the walls were designed of reinforced concrete, due to scarcity of lumber and high shipping freights, naturally the contractors proposed concrete blocks, having the sand and stone on the site, and being the owners of four Ideal block machines, U.S.A. make.

A further Italian concrete brick machine, which could turn out twelve bricks at one operation, was purchased locally.

The cold storage building, illustrated, was made of solid concrete blocks, 16 in. × 6 in. × 6 in., $1 : 2\frac{1}{2} : 5$ concrete; the blocks were kept solid to prevent radiation of temperatures, the same afterwards being plastered with a cement gun.

The main sewer line for all factory waste was laid with concrete pipes 16 in. internal diameter fabricated on site with 1 cement and 7 sand.

View showing Concrete Sewer Pipe.

Showing the Italian Concrete Brick Machine.

To date the factory is in operation and giving satisfactory results as regards the walls and sewer line.

Temperatures during the winter months are very low, this being at a longitude 52° F. South. In summer it can be so high as 95° F., which is a high contrast to the winter months which have been known to go down to 20° F. below 32° F. (12° F.) and six hours daylight.

To the Editor of CONCRETE AND CONSTRUCTIONAL ENGINEERING.

DEAR SIR,—As Reinforced Concrete surfaces for roads are here to stay, and will be used extensively throughout the country, could not some standard method of construction be established by some recognised authority?

The information that has been published up to the present time has been most varied and contradictory as to the best method of making this type of road. Take the mixing of concrete. Some engineers will advocate a dry mixture, using not more than 10½ gals. of water to the cubic yard of concrete, and yet one sees quite frequently a very wet or sloppy mixture being used, which in the writer's opinion should not be, as the fine particles of stone and the finest particles of cement separate and rise, forming a thick scum at the top. This is where the slab should be most enduring, but if too much water is used, a material having about the resistance and character of chalk is substituted for the enduring material desired.

Tamping of Concrete.—I do not think that sufficient care is exercised in tamping the concrete. One sees either too much or not enough. Too much brings the lighter materials to the surface, which is not advisable. A hand-tool, shaped as a "grid," about a foot square, made of heavy wire, attached to a wooden handle, has proved satisfactory, or even a light hand roller, where a dry mixture is being used.

Reinforcement.—The placing of this material, either at the top or bottom of the slab, has often been under discussion, yet the majority of engineers would require a lot of convincing before believing that the steel mesh is not of more value at the bottom, and better still, if placed in both top and bottom, as the stress that occurs in a road slab is very similar to a continuous floor slab, where tensile stresses occur in both top and bottom the reinforcement at the top will also act as temperature reinforcement.

Types of Mesh.—We in England have followed the American method of reinforcing roads, which is not necessarily the best way. Another method is the use of a square mesh which has the same area of steel in both directions, now on sale in this country. This was designed in the belief that a wheel load, when applied to the slab, will cause stresses both longitudinally and transversely.

I suggest that the Concrete Institute or some other authority should get together some data in a pamphlet form regarding the proper design and method of construction of concrete roads.

This would be very useful to both contractors and engineers interested in this work.

Yours faithfully,
W. S. PEGGS,
Chief Engineer,
Brown & Tawse, Limited.

MEMORANDA.

The American Concrete Institute.—The Institute held its Annual Convention last month and, as usual, a very varied and interesting programme was before the members for discussion. Up to the time of going to press we have not seen any of the Papers read, but from the preliminary particulars received, we gather that every aspect of concrete construction was to be dealt with, and we hope shortly to be able to give an account of the proceedings of the Convention.

Concrete Work on the South African Government Railways.—In connection with improvements and relocation work which is being done on a stretch of railway line between Durban and Pietermaritzburg, a considerable amount of concrete construction will be carried out. There will be ten tunnels required, all of which are to be lined in concrete. Further, a concrete bridge across the Umhlatuzan River with seven arch spans of 30 ft. is the most important structure on the line. Concrete piers and pile foundations carry a double track bridge which crosses the same river near Clairwood. A 30-ft. arch culvert has also been constructed. The improvement works are being carried out under the direction of Sir W. W. Hoy, General Manager, Railways and Harbours, Union of South Africa.

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

In response to a very general request we are re-starting our Questions and Answers page. Readers are cordially invited to send in any questions. These questions will be replied to by an expert, and, as far as possible, they will be answered at once direct and subsequently published in this column for the information of our readers, where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—ED.

Question.—S. E. F. writes :—In your January Number there appears an interesting article on the "Artistic Side of Concrete," which, however, is on very general lines. I should be glad to know of any bibliography on this subject and the results, as far as published, of the most recent research in this direction, particularly with respect to the effect on the physical properties of the concrete of the various colouring matters added. Special mention is made in the article of the absorptive method. I should be glad to have further details of this method, and any assistance you can render me in getting me into touch with the latest information.

Answer.—The effect of the addition of pigments is to reduce somewhat the strength of the concrete, since they are all more or less of a soft nature and take the place of harder and stronger material. Mineral colouring matter only should be employed.

Experiments made with a view to determining the effect of various pigments upon the setting time of cement showed that the addition of ferric oxide, yellow ochre, ultramarine and chromium resulted in a very slight quickening, crimson lake made it set quickly, and barium chromate quickened it very considerably. On the other hand, manganese oxide, red ochre and Chinese red had a slowing effect.

In the absorptive method, solutions of certain metallic salts which supply the colouring matter are applied to the concrete, either by means of a brush or by immersion. The solution penetrates the material to a depth of, in some instances, an eighth of an inch, the pores are filled and a dense hard surface is the result.

This subject was dealt with briefly in CONCRETE AND CONSTRUCTIONAL ENGINEERING in March, 1920, and more fully in the issue of April the same year, under the title "The Metallisation of Cement." We know of no bibliography on the subject of the artistic side of concrete other than the pamphlet *Concrete, its Artistic Possibilities*, issued by the Concrete Utilities Bureau, 35, Great St. Helens, London, E.C. 3. This pamphlet may be obtained free of charge.

MEMORANDUM.

Installation of Extensive Gas Works Plant in Reinforced Concrete.—A comprehensive construction scheme costing £250,000 and involving reinforced concrete structures of many types is now nearing completion at Provan Gas Works, of the City of Glasgow Corporation. The work is designed by Mr. B. N. Dey, B.Sc., A.M.I.C.E., of Messrs. Economic Structures Company, London, the contractors being Messrs. Gray's Ferro-Concrete Company, Glasgow, Mr. Dey acting as consulting engineer.

The main structures are : (1) The purifier house, 505 ft. long and 100 ft. wide. The ground floor, which is of concrete, carries numerous 2 ft. 6 in. gauge railway tracks, valve seatings, gas mains supports and columns supporting 24 large overhead purifier tanks. (2) A revivifying floor, 100 ft. wide and of the same length as the purifier house being built within it at a height of 30 ft. above ground level. (3) Three separate houses each containing one pair of purifier boxes. (4) An oxide store with a floor area of 150 ft. by 200 ft., separated from the purifier house by a reinforced concrete retaining wall 200 ft. long and 30 ft. high. The store contains three 4 ft. 8½ in. gauge railway tracks carried on reinforced concrete piers and girders. Two large platforms supported on beams and columns of reinforced concrete carry the disintegrator machinery and the motor house. It is estimated that approximately 6,000 cu. yds. of concrete, excluding that for foundations, and 500 tons of steel rods have been used and 30,000 sq. yds. of shuttering have been employed.

LEAVES FROM THE DIARY OF A PRACTICAL CONCRETOR.

Having been associated with the cement trade the whole of my life, both as a working concretor and a Master, the conclusion at which I have arrived is that the only way to learn concrete is to handle the tools, and it is now my earnest desire to see a better concrete produced than some I daily come in contact with. Cement-making has been brought to a " Fine Art," and there is no reason why we should not endeavour to raise the standard of concrete likewise, by using more suitable and cleaner aggregate, and by better manipulation under stricter supervision.

In my working days we were making partition slabs with a specification of 4 to 1 clean coke breeze and cement, but during and since the War, we have drifted into a 6 to 1 specification, or even poorer than this, and not always with a similar breeze, but boiler ashes containing a large percentage of coal, or a destructor clinker, which often contains free lime ; neither of these aggregates is conducive to good concrete. Quite recently I observed in a contractor's yard slabs being made with this boiler ash aggregate, which was extremely dirty and contained the deleterious ingredients mentioned. As soon as the slabs were made they were placed in the open yard, with the broiling sun playing on them, which of course meant that they were drying out and thus spoiling the natural crystallisation of the cement.

For many years I have been studying aggregates all over the country, but I find to-day the same idea which prevailed twenty-five years ago, viz. that any old stuff will make concrete. I assume that to-day we are in a concrete age, but I am afraid concrete will have a very serious set-back unless greater consideration is given to its admixture and the impression that " anything will do " is obliterated.

It often appears to me that with masters, foremen and workmen, the minor details (as they appear to them) are frequently overlooked, and they run away with the idea that one cement is suitable for doing everything, such as foundation concretes, reinforced concrete, plastering, pipe jointing, and many other things. This, however, is not the case ; for instance, pipe jointing cement is not suitable for reinforced concrete, and so on. One of the first things, to my mind, is that the man in charge of a job should make rough tests finding out the initial and final sets of the cement he is about to use. This I always find is a very vital point, especially the initial set of the concrete.

In the many jobs which come under my observation, concrete is very often " killed " before it is put into position, through the concrete, already mixed, standing during meal hours. When the men return from meals the initial has gone, and they immediately add more water, knock it up again and put it into position. They then realise this does not set so freely as that alongside it, and then there is, of course, only one thing to blame, viz., the cement, and the remark is made that those two bags were nothing like as good as the others. This, of course, is not quite fair to the cement or to the manufacturer.

An incident happened recently, when a foreman took from a batch of mixed concrete a portion of it to make into 4-in. cubes for testing purposes. It was a 4-2-1 mixing and placed in 4-in. steel moulds which are always essential, but when the cubes were made they were placed *outside* a shed where the sun and wind could attack them, and when tested they realised but a very poor crushing strain and upon examining these broken cubes I found the concrete "dead," having again dried out instead of crystallising out. The foreman made me up a box of his gravel, sand, and a portion of the cement he had used, and I made these into cubes and placed them in a proper place for maturing, and when broken at seven days they realised a crushing strength three times greater than their own. Now a little thought would have obviated all this trouble and worry, as the actual concrete was perfectly good.

These points are given as an illustration of facts, and if these minor details were given the necessary thought, we should have better concrete produced. A little knowledge in regard to cement or concrete testing often proves very dangerous.

In a cement of present day manufacture, we have the most sensitive article used on a building, owing to its fine grinding, and yet unfortunately this material receives the least care or supervision.

I pointed out to a man some few months ago, who had been doing some pipe jointing which had cracked badly, that his methods were not correct as far as my experience had taught me. The cracking in the first place was due to the use of a neat cement instead of a mixture of 1 to 1 with good clean washed sand. Secondly, the pipes had not been properly soaked to stop the absorption at the unglazed socket and spigot ends. Thirdly, the work had not been protected from the sun.

While I am on this pipe jointing question there is one other serious point which many workmen overlook, that is when buttering the flange of the socket, they seldom butter the end where the spigot meets the other pipe, so that they get pipe on pipe which is seldom true in surface, consequently the water gets down this rough surface and causes sweating of the joints. This portion should be buttered as well as the flange and the other pipes butted well on to it and then wiped on the inside with a piece of rag.

MEMORANDUM.

Concrete Safes.—The ingenuity of some thieves is notorious, and the rapidity with which they have made use of the cutting power of the oxy-acetylene flame for opening any kind of iron or steel safe is worthy of a better cause. It has, however, been the means of placing on the market a new kind of safe which, whilst not impervious to such a flame, produces such a loud noise, of the nature of explosions, when subjected to it that, except in the most isolated districts, they would soon attract a crowd of inquirers and make the escape of the thieves very difficult.

The new material is nothing less than an ingenious arrangement of reinforced concrete, and is solely composed of a mixture of boring and turning specially hard steel, with concrete completely surrounding a massive reinforcement, designed to give the maximum resistance to fire, falls, or blows.

Safes built in accordance with the Thorig system do not require either coating or lining; they are strictly monolithic and can be of any desired size or shape. The rounded arrises and corners made possible by the use of concrete are an added advantage.

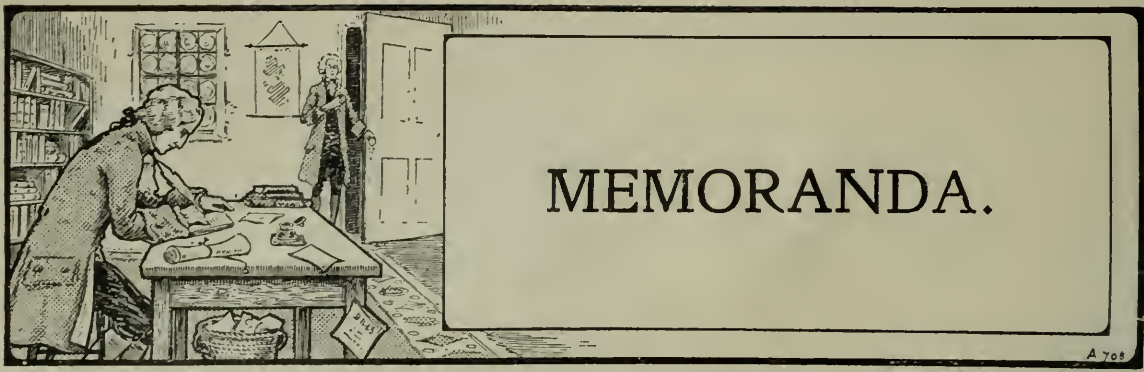
So hard is the combination of steel fragments and concrete that these safes cannot be drilled, but to make assurance doubly sure the safes could be cased and lined in the customary manner if desired.

In appearance these safes resemble the best steel safes (see Illustration, p 217) and they are fitted with locking devices of the most approved patterns. The door opens readily when the safe is unlocked, and when shut is quite dust-proof as well as damp-proof and makes the contents wholly inaccessible to any thief.

A leading insurance company in Vienna, we understand, has definitely undertaken to allow a rebate of 50–70 per cent., according to the amount insured and the size of the safe, on all insurance premiums paid in respect of articles kept in a Robur Steel Concrete Safe.

The same principle can be applied with equal success to strong room doors and for other purposes. The makers are the Robur Stahlbetonkassen G.m.b.H., Vienna.

The safes are at present made in seven sizes, the smallest measuring internally 16 in. × 12 in. × 7½ in., and the largest 63 in. × 28 in. × 20 in., the walls of the smallest size being about 4 in. thick whilst those of the largest are about 6 in. thick.



Memoranda and News Items are presented under this heading with occasional editorial comment. Authentic news will be welcome.—ED.

Lecture.—On February 24 a lecture was delivered by Mr. T. J. Clark, manager of the Concrete Utilities Bureau, before the Cambridge University Agricultural Society, the subject being "The Application of Concrete to Agricultural Purposes." The lecturer first briefly outlined the manufacture of Portland cement, passing on to the properties which make concrete especially suitable for agricultural uses, and then described in detail many of the ways in which the material could be used on the land. These included farm buildings, tanks, troughs and cisterns, septic tanks, drain and sewer pipes, well linings, pigstyes, poultry-houses, floors, manure-pits and tanks, culverts, silos, fencing, greenhouses and garden frames, rick stands, farm roads, and many others. The lecture was illustrated by a large number of lantern slides.

Relation between Moulded and Core Concrete Specimens.—Mr. H. S. Mattimore, Engineer of Tests, Pennsylvania State Highway Department, has recently carried out some tests to show the relative strength of moulded and core concrete specimens. In an article in *Engineering News Record* he relates the result of this piece of research. He says that for many years compression strength of concrete has been determined, to a large extent, by the strength obtained on specimens moulded of a mix proportioned the same as that used in the structures under consideration. These specimens, at first, were made entirely in the laboratory under ideal laboratory conditions. Further development along this line was the moulding of specimens at the construction site.

A study of the comparative results of these tests on laboratory and field-moulded specimens revealed, in numerous cases, a considerable difference in strengths in mixtures of the same proportions. Studies to determine the reasons for these differences have resulted in considerable progress towards rational design of concrete mixes. This is due mainly in determining many factors which have their effect on field-mixed concrete.

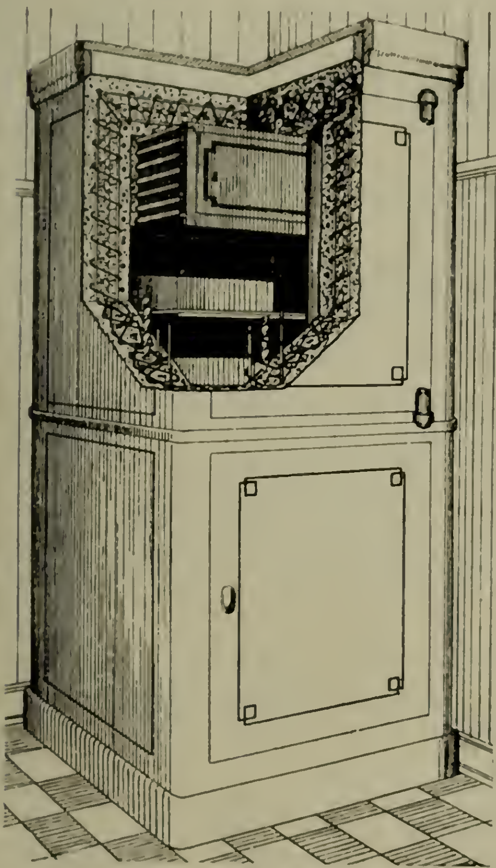
TABLE I—COMPARISON OF MOULDED AND DRILLED CONCRETE SPECIMENS—1 : 2 : 3 MIX

Compression Strength Lb. per Sq. In.

	Moulded Specimens				Drilled Specimens				
Series No.	Age Days	Max.	Min.	Mean	Age Days	Max.	Min.	Mean	No. of Spec.
1	28	4,740	2,690	3,545	330	6,061	4,210	4,728	5
2	28	4,054	2,211	3,095	300	6,070	3,980	4,543	13
3	28	3,315	2,115	2,788	300	5,452	3,860	4,706	5
4	28	4,357	2,229	3,368	300	6,585	4,185	5,288	8
5	28	3,896	2,646	3,397	320	5,001	3,047	3,907	7
6	30	3,928	3,215	3,505	300	5,672	3,868	4,966	9
7	7	1,992	1,405	1,721	60	4,599	3,402	4,044	4
8	7	2,486	2,123	2,285	90	5,454	4,769	4,993	4
9	7	2,914	1,374	2,016	150	6,598	3,930	5,304	11
10	28	3,525	1,884	2,524	400	5,468	3,539	4,669	8
11	28	3,566	2,234	3,055	460	5,468	3,676	4,954	4
12	7	2,420	1,947	2,042	80	6,286	3,517	4,561	8
13	7	2,960	1,876	2,241	140	5,613	3,664	4,399	9
14	7	3,118	1,847	2,233	150	4,423	3,345	3,634	5

Table I is a summary of data on moulded and drilled concrete specimens, obtained during construction and from the finished pavement of the Pennsylvania highways. The moulded specimens were cast in the field and cured under the same conditions as the pavement. The drilled specimens are cores taken from the finished pavement by a field core drill.

It will be observed that the general tendency is toward considerably higher strengths in the drilled specimens. This is affected to some extent by the difference in age, but the variation in age in the drilled specimens of the different series also indicates that other factors exert a greater influence than the age. Further, the strength of the moulded specimen is not a positively reliable indicator of the strength of the concrete in place, as determined by the drilled specimen. This fact further demonstrates itself in Table II, which illustrates the detail test of one of the series from which the summary is compiled. It is also especially notable in this table that the drilled cores of the highest strengths are not always opposite the moulded specimens of the highest values.



Reinforced Concrete Safes (see p. 215).

TABLE II.—DETAIL DATA OF SERIES NO. 2 (Table I)

Moulded Specimens		Drilled Specimens		1 : 3 Sand Mortar Tension 7 days		Cement Tensile Strength	
Age	Strength	Age	Strength	Lb. per sq. in.	Per cent. Ottawa	7 day	28 day
28	3,526	360	4,757	307	133	280	393
29	4,054	330	5,353	313	105	280	393
28	3,331	330	5,141	318	103	280	393
28	3,061	240	5,070	312	121	280	393
28	3,304	240	6,070	442	161	280	393
28	2,783	240	3,980	315	124	280	393
28	2,211	210	4,650	428	178	280	393
28	2,821	240	3,931	...	102	280	393
28	2,489	270	4,640	383	147	280	393
28	3,152	270	4,025	317	125	280	393
28	3,146	300	4,405	312	113	280	393
28	2,528	300	5,024	314	118	280	393
28	3,834	330	4,008	311	107	280	393

Present Value of Compression Tests.—Although preliminary tests on moulded field specimens are not a positively reliable indicator of the strength of the concrete in the finished structure, they have a great value on individual projects, and such

control should be encouraged. Moulded specimens taken at regular periods on any concrete construction will indicate any great difference in strength and lead to a investigation of causes. So far as the writer knows this is the only method of detecting these defects, and an experience of six or seven years of this method of control has proved an economic procedure.

At the same time he maintains that extensive tests should be carried on to determine the comparative relations between moulded and drilled specimens. The drilled specimens furnish us with an assurance of the actual strength obtained. The test on these latter has been of inestimable value in our work. Reference to Tables I and II gives us convincing proof that our pavements have an excellent factor of safety so far as compression strength enters into the design.

TRADE NOTES, CATALOGUES, &c.

Considère Construction Co.—We are asked to announce that the Considère Construction Company, the well-known firm of Specialist Designers in Reinforced Concrete, have moved to larger and more convenient offices at 72, Victoria Street, S.W.1. Their Telephone Number will remain unaltered, viz., Victoria 3033.

Road Reinforcement.—Messrs. Brown & Tawse, of 3, London Wall Buildings, E.C.2, have sent us their catalogue describing their road reinforcement mesh. This reinforcement mesh is made both square and longitudinal from square twisted wires and the cross wires are so interwoven with the longitudinal wires or tension members that the latter are held in position by the natural lock created by the twisting of the material. The material is also made up in suitable widths for reinforcing brickwork.

The catalogue also contains particulars and illustrations of the firm's stirrups and links, as well as their pile frames, manufactured complete with shoe ready for concreting.

There are also some useful notes regarding the construction of reinforced concrete roads, as well as a number of reference tables for the engineer desiring to use B. and T. reinforcement.

Stanton Hume Concrete Pipes : Period of Loan.

Dear Sir,—My attention has been drawn to a notice in the Technical Press, doubtless inspired by friendly competitors, to the effect that the Ministry of Health will grant loans to local Councils for the full term, for work in which granite concrete sewer tubes are used. This I understand also to be the case where earthenware pipes are used. And it is certainly the case where concrete pipes on the Stanton Hume principle are concerned, although this may not be generally appreciated.

The Stanton Hume Concrete Pipe is being made without reinforcement in lengths not less than those usual with other concrete and earthenware pipes, and it is capable of withstanding the maximum pressures usual with this class of pipe.

But where higher internal and external pressures have to be met, or where longer lengths are desired in order to effect a saving in the jointing, the Stanton Hume Pipe is being built with a reinforcement which enables working pressures to be met that are outside the practical scope of non-reinforced concrete pipes or of earthenware pipes.

Yours faithfully,

For the Stanton Ironworks Company, Limited,

E. J. FOX, Managing Director.

"Winget's" Stand at the Ideal Home Exhibition.—(No. 65 Main Floor).—Among other novel features on the "Winget" Stand is demonstrated the new system of concrete block construction by means of which some houses are now being built in the *Daily Mail* Model Village at Welwyn Garden City, Herts. No two blocks are exactly alike in colour or texture in this type, which offers a new field for architects and removes every objection to concrete buildings on the ground of monotony of appearance. There are working examples of various concrete block, brick and tile making machines including the No. 3 "Winget" Pressure Machine. The Stand also includes both Crushers and Crushing Rolls—the latter another addition to the "Winget" plant capable of reducing 6 to 7 cubic yards clinker to ¼ in. and under per hour—as well as the standard Chain-Spade machine for semi-wet mixing. The "Dekko" Portable Conveyor, capable of loading or unloading a ten-ton truck or steam wagon with two men in twenty minutes is also shown.

The Victoria CONCRETE MIXER

THIS illustration shows one of our concrete distributing plants designed to serve an area of 100 feet radius. The chuteing is divided into two sections, the outer section being balanced. By this means it is possible to deliver the mixed concrete anywhere within this radius, speedily and with a minimum of labour and effort.

We are also able to supply single units from a large variety of Concrete Mixing Machines suitable for every purpose. We cordially invite you to visit us at our new premises, where we have a specially prepared floor which will enable us to exhibit our machines actually running, or we shall be glad to send you fullest particulars on request.

STOTHERT & PITT, LTD.
(MIXER DEPT.)
Orchard St., Westminster
S.W.1.

TENDERS ACCEPTED.

GUERNSEY.—The tender of Mr. N. Buckley, of Dorchester Road, Weymouth, has been accepted by the Guernsey Water Board for the construction of two concrete and masonry filter beds, a covered water tank of 125,000 gallons capacity, and concrete foundations for engines and pumps.

LEEDS.—The Leeds Town Council has accepted the tender of the Yorkshire Hennebique Co., at £3,298, for the construction of an overhead tank at Moor Town.

LONDON (LEWISHAM).—The Lewisham Borough Council has accepted the tender of Messrs. Johnson's Reinforced Concrete Engineering Co., Ltd., for the supply of 1,200 yards of steel wire lattice reinforcement for use in the construction of an open-air swimming bath at the Bellingham housing estate.

LONDON (STEPNEY).—The tender of Messrs. W. J. Jarvis & Sons, Ltd., of Hackney, at £390, has been accepted by the Stepney Borough Council for the construction of concrete flooring at the Osborn Street electricity sub-station. Other tenders received were: W. Harbrow, Ltd. (Bermondsey), £573; Holloway Bros., Ltd. (London), £619; D. T. Jackson (Barking), £769.

SUNDERLAND.—The tender of Messrs. Robert Hudson & Sons, Ltd., of Sunderland, at £11,850, has been accepted by the Sunderland Gas Company for the construction of a mass concrete gasholder tank (125 ft. 6 ins. in diameter by 28 ft. 8 ins. in depth).

WINCANTON.—The Wincanton Rural District Council has accepted the tender of Messrs. H. C. Pullar & Co., of Manchester, at £7,246 18*s.* 1*d.* for the construction of a reinforced concrete service reservoir, laying about 7,300 yards of water mains, and other works. Other tenders were: W. Muirhead, Macdonald, Wilson & Co., Ltd. (Birmingham), £7,765 9*s.* 5*d.*; H. E. Brixey & Co., Ltd. (Parkstone), £8,152 19*s.* 2*d.*; Bird & Pippard, Ltd. (Yeovil), £8,179; Hull & Sons (Nottingham), £8,305; W. Parsons & Sons (Crewkerne), £8,400; S. Ambrose (Bath), £8,425 17*s.* 1*d.*; G. Pollard & Co., Ltd. (Taunton), £8,472 12*s.* 4*d.*; T. Muirhead & Co., Ltd. (London), £8,571 10*s.*; Johnson & Langley, Ltd. (Leicester), £8,711 15*s.* 2*d.*; H. Butt (Wincanton), £8,880; Smith & Marchant (Shepton Mallet), £8,946 2*s.* 6*d.*; R. G. Spiller (Sherborne), £8,990; Hardy & Co. (Woking), £9,500; E. Ireland (Bath), £9,673; H. Middleton (Hatfield), £10,068 1*s.* 2*d.*; E. G. Padfield & Co. (Shepton Mallet), £10,665; T. Bugbird & Son (London), £11,121 7*s.* 5*d.*; Unit Construction Co. (London), £12,486 2*s.* 1*d.*; S. Dowding, Ltd. (Southampton), £10,285 10*s.*; H. Pittard & Son (Langport), £12,833; F. Mitchell & Son, Ltd. (Manchester), £8,495 15*s.*; Grounds & Newton (Bournemouth), prime cost plus 7½ per cent.

WORCESTER.—The Worcester Town Council has accepted the tenders of Messrs. T. Broad, Ltd., of Malvern, for the construction of a reinforced concrete reservoir at Rainbow Hill (£3,831 9*s.*), and a reinforced concrete reservoir at Elbury Hill (£4,026 2*s.* 7*d.*).

PROSPECTIVE NEW CONCRETE WORK.

ABERDEEN.—*Road.*—The Aberdeen Corporation is considering the question of constructing a new road between Old Aberdeen and Woodside, at an estimated cost of £15,000.

ABERYSTWYTH.—*Sewage Disposal.*—An inquiry has been held by the Ministry of Health into the application of the Aberystwyth Town Council for permission to borrow £34,600 for sewage disposal works.

ADWICK.—*Reservoir.*—Plans have been approved by the Adwick Urban District Council for the erection of a surface reservoir, water tower, and other works.

BARRY.—*Sea Defence.*—The borrowing of £9,300 by the Barry Urban District Council for the construction of a sea wall has been sanctioned by the Ministry of Health.

BIRMINGHAM.—*Road.*—The construction of a new road between Birmingham and Wolverhampton, at a cost of about £400,000, has been approved by a conference of local authorities in the Midlands.

BRIDLINGTON.—*Road.*—A new road from Cardigan Road to Fraisthorpe is to be built by the Bridlington Town Council, at an estimated cost of £37,000.

CLEETHORPES.—*Open-air Bath.*—A proposal of the Cleethorpes Urban District Council to construct an open-air bathing pool, at a cost of £20,000, has been the subject of an inquiry by the Ministry of Health.

COLDSTREAM.—*Concrete Paths.*—The Coldstream Town Council has decided to obtain tenders for the construction of concrete footpaths on the site of its housing scheme.

CREWE.—*Sewage Works.*—An inquiry has been held by the Ministry of Health into an application of the Crewe Town Council for permission to borrow £39,000 for sewage and sewage disposal works.

DURHAM.—*Reservoir.*—Application has been made to Parliament by the Durham County Water Board for sanction to a loan of £1,686,000 for the construction of a reservoir at Burnhope.

FOLKESTONE.—*Sewage Works.*—The Folkestone Town Council has approved a scheme for the extension of the sewage outfall works, at a cost of £46,000.

GLASGOW.—*Concrete Wall.*—The Clyde Trust has authorised its engineer to proceed with the work of replacing the present wooden structure at Broomielaw Quay with a concrete quay wall, at an estimated cost of £8,000.

GLASGOW.—*Bridge.*—The Glasgow Corporation is considering the question of erecting a bridge across the river Cart at Pollokshaws.

HENDON.—*Open-air Bath.*—Permission has been granted by the Ministry of Health for the Hendon Urban District Council to borrow £5,000 for the construction of an open-air bath.

HULL.—*Bridge.*—The Hull Town Council has decided to seek Parliamentary powers for the erection of a bridge across the Humber.

ILKLEY.—*Sewage Works.*—Extensions at the sewage disposal works are to be carried out by the Ilkley Urban District Council, at a cost of about £7,000.

ISLE OF MAN.—*Harbour Works.*—The Manx Legislation has been recommended by the Isle of Man Harbour Commissioners to carry out extensive developments at the port of Douglas, at an estimated cost of £282,000.

LEAMINGTON.—*Bridge.*—In connection with a proposed new road, the Borough Surveyor has submitted to the Leamington Town Council an estimate of £12,000 for the construction of a reinforced concrete bridge across the river Leam.

LEEDS.—*Roads.*—The Ministry of Health has sanctioned the borrowing by the Leeds Town Council of £184,000 for the construction of two new roads, one for Elland Road to Gelderd Road and one from Buslingthorpe to Moortown.

LEWES.—*Bridge.*—The Lewes Town Council has approved plans prepared by the Borough Surveyor for a new bridge over the river, to replace the present bridge, which is in a dangerous condition.

LITHERLAND.—*Road.*—The Lancashire County Council has decided to proceed with the construction of a new road at Litherland, at an estimated cost of £39,000.

MANSFIELD.—*Sewage Disposal.*—An application has been made to the Ministry of Health by the Mansfield Town Council for sanction to a loan of £14,800 for extensions at the sewage disposal works.

MIDDLESEX.—*Bridge.*—Sanction has been received by the Middlesex County Council from the Ministry of Health to a loan of £7,847 for the rebuilding of the bridge at Greenford.

NEWARK.—*Sewage Works.*—Application has been made by the Newark Urban District Council. to the Ministry of Health for sanction to borrow £55,000 for sewage disposal works.

NEWBURGH.—*Bridge.*—The Aberdeenshire County Council has under consideration a proposal to erect a new concrete bridge at Waterside, Newburgh, at an estimated cost of £23,000.

NORTHAM.—*Reservoir.*—The Ministry of Health has sanctioned the borrowing by the Northam Urban District Council of £7,200 for the construction of a reservoir at Melbury.

NORTHAMPTON.—*Reservoir.*—The Northampton Town Council is considering the construction of a reservoir at Hollowell.

NORTHAMPTON.—*Sewage Works.*—The Northampton Town Council is considering the question of the removal of the sewage works on the Houghton Road to a different site.

PORTSMOUTH.—*Harbour Works.*—In connection with the proposed new harbour works, the Portsmouth Town Council has been recommended by the Docks Committee to proceed at once with certain portions, for which estimates for timber and concrete construction have been prepared by the Borough Engineer.

ST. JUST.—*Reservoirs.*—The St. Just Urban District Council has received sanction to the construction of two reservoirs (with concrete floors), at an estimated cost of £7,800 and £3,500 respectively.

STOCKPORT.—*Sewage Works.*—The Stockport Town Council has decided to apply to the Ministry of Health for sanction to a loan of £200,000 for the construction of detritus and other tanks, filters, and other works at the sewage disposal works.

STRETFORD.—*Bridge.*—A new bridge is to be built by the Stretford Urban District Council, at an estimated cost of £40,000.

SUNDERLAND.—*Sea Defence.*—The Board of Trade has been approached by the River Weir Commissioners for permission to extend the sea wall to the north of the South Pier.

SURREY.—*Road.*—A conference has been held between the Ministry of Transport and the neighbouring local authorities on the question of the construction of an arterial road between Kingston and Esher, at a cost of £290,000. The conference favoured the proposal, and a further conference is to be held.

WEALDSTONE.—*Open-air Bath.*—An open-air swimming bath is to be constructed by the Wealdstone Urban District Council, at a cost of £2,500.

NEW COMPANY REGISTERED.

ATLAS CONCRETE SLAB AND BLOCK CO., LTD. (179572). Registered February 9. Paviors and manufacturers of and dealers in concrete and artificial stone slabs and blocks. Nominal capital, £1,000 in 1,000 £1 shares. Directors: T. Rodgers, P. J. S. Nicholl, J. Seymour, H. E. Jones, and W. G. Cook (1, Newcomen Road, Leytonstone). Qualification of Directors, one share; remuneration, to be voted by Company.

RECENT PATENT APPLICATIONS.

157,130.—R. Hofler and S. Renyi: Building blocks and slabs.

172,664.—C. J. Mannell: Concrete block-making machines.

172,669.—J. T. Sentrop: Floor construction.

172,677.—H. Loesch: Moulds for use in concrete house construction.

172,773.—F. W. Bradshaw: Reinforced concrete girders or beams.

172,778.—R. A. Inglis: Reinforced concrete structures.

172,794.—D. Malcolm: Wall ties.

172,800.—T. A. Locan: Building construction.

172,855.—E. G. Clarke: Concrete block-making machine.

173,007.—F. S. Sumpter: Hand press for the manufacture of concrete blocks.

173,015.—C. A. H. Brown: Wall construction.

173,045.—E. Airey: Concrete blocks, piers, and pillars.

173,055.—B. Maddock: Building blocks.

173,058.—J. Blunn: Reinforced concrete floor and ceiling slabs.

173,103.—G. B. Araldo: Building blocks or slabs.

173,351.—W. G. Shipwright: Reinforced concrete floors.

173,401.—F. E. G. Badger: Concrete blocks.

173,577.—S. H. Norman: Concrete and reinforced concrete construction.

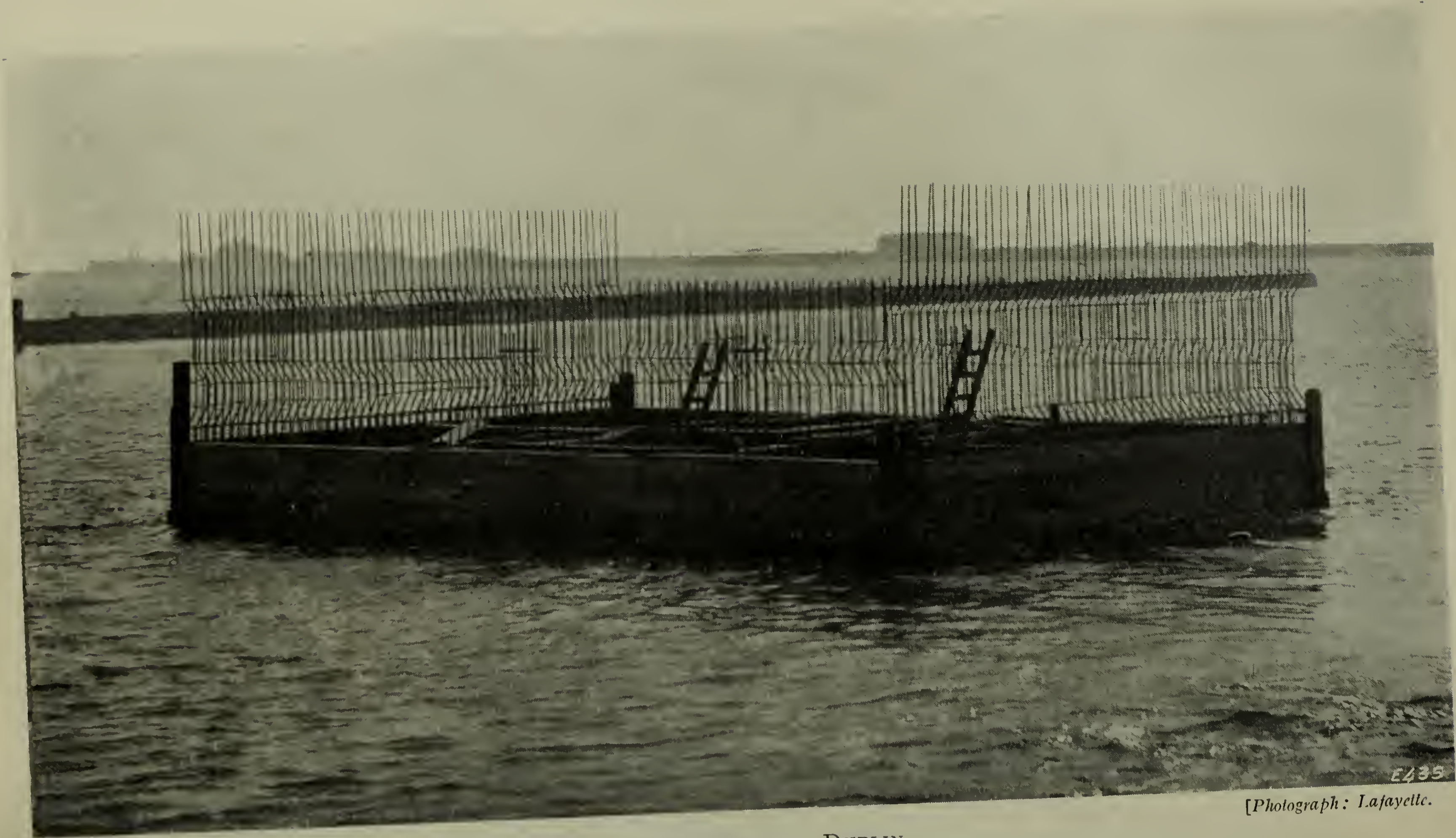
173,823.—A. O. Crozier: Manufacture of cementitious products.

173,862.—E. O. Williams: Reinforced concrete floor construction.

173,870.—F. Lichtenberg and M. McCarthy: Building blocks and buildings.

173,876.—J. Morgan: Wall construction.

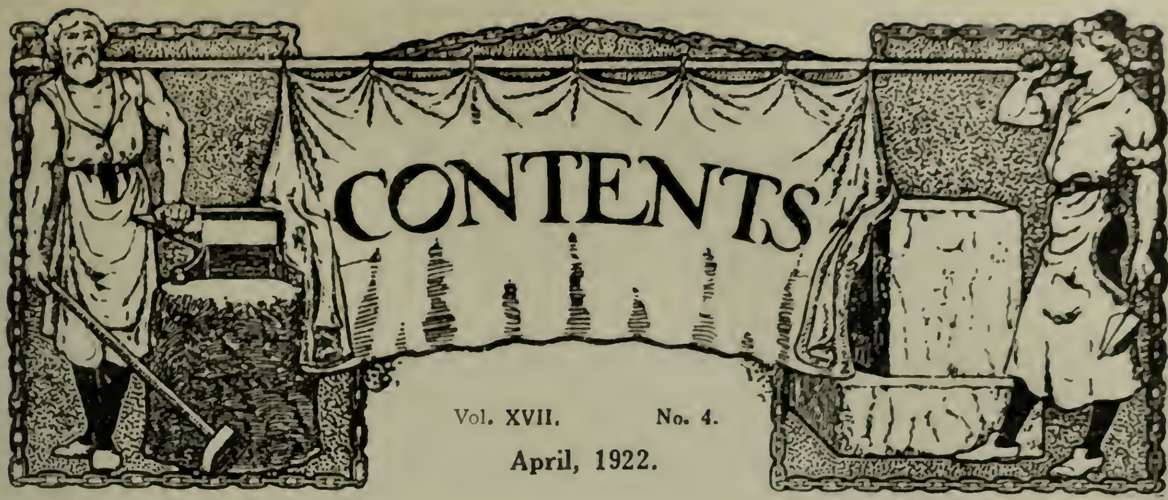
173,931.—J. J. Eagan: Concrete ship construction.



[Photograph: Lafayette.

CONCRETE CAISSON AT DUBLIN.

(See page 243.)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April, 1922.

BUILDING EXHIBITION, OLYMPIA, APRIL 11-27.
Write to RANSOMES, DEPT. B, for FREE ADMISSION TICKETS.

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 4. LONDON, APRIL, 1922.

EDITORIAL NOTES.

CONCRETE AND DESIGN.

It is no exaggeration—in fact, it is almost a platitude—to state that the extraordinary development of reinforced concrete within recent years has so widened the scope of the architect and the builder as to have opened up an entirely new field in design and construction. After the lapse of centuries, concrete is again becoming one of the principal building materials, and, although what may be called its "re-discovery" is only in its infancy, with the use of scientific methods of reinforcement it has already made possible the erection, among other structures, of the huge "skyscrapers" which are such a source of wonder to visitors to America.

Each discovery of new building forms and materials in the past has led to periods of great architecture, and there can be no doubt that we are now on the verge of still greater developments in the application of concrete to building which, if handled in the right spirit, will produce architecture in every way comparable with, and there is no reason why it should not surpass, the best work of the great mediæval periods. To achieve this, however, it is essential that concrete should be frankly accepted as a new building material. It is generally admitted that the addition of the stone covering to the steel framework of the Tower Bridge detracted from the fine effect of a "gateway to the sea" which the bare steelwork expressed, and it cannot be denied that the stone face of some large concrete buildings has detracted from rather than enhanced the appearance of the finished work. The finest architecture of the past has been achieved not by disguising one material with another, but by the acceptance of a material as a medium of construction and obtaining effect by the disposal of the various parts to form an harmonious whole and by careful attention to details. In a modern concrete building the concrete and steel are entirely self-supporting and take the weight and stresses of the other component parts ; is it not, therefore, illogical and an unnecessary addition to the cost to clothe such a structure with stone ? The argument advanced against a concrete surface is its undeniably dull and monotonous appearance in large, flat areas, but some buildings have been erected in London in recent years in which no attempt has been made to hide the concrete, but in which any tendency to monotony has been very successfully overcome by careful design. A material which presents to the architect such great and new possibilities as reinforced concrete should not be bound by the rules of design which govern brick and stone construction, or dressed up in an entirely superfluous covering in some traditional style which has been evolved for a different material. If used intelligently and sympathetically it will, in time, form a tradition of its own.

Signs are not lacking, however, that serious attempts are now being made to produce a more attractive surface to concrete. Various methods are being adopted, such as exposing the aggregate by scrubbing the cement from the surface before it has finally set, or, in the case of blocks, covering the face with a layer of cement coloured to any desired tint. Considerable interest is now being taken in the question of brightening the streets of London by the introduction of colour on the façades of buildings, and the fact that the Royal Institute of British Architects has instituted a competition for an office building with a coloured frontage supports our opinion that these experiments are on the right lines. In America, where much experimental work has been done in this direction, excellent results have been obtained, and in this country some attractive houses in which blocks of different colour have been used have been erected at Liverpool, Welwyn Garden Village, and elsewhere. The artistic possibilities of concrete are not as yet fully appreciated, certainly not as much in this country as in the United States, and a great deal remains to be done not only in research and experimental work but in making the results known to the general public. It is not looking too far in the future to anticipate the revival of small house building. Whether that work will be undertaken by the Government or by private enterprise we do not know, although most probably it will be the latter ; but it is obvious that houses will have to be built, and a campaign to popularise what might be called the " new concrete " would do much to dispel the idea that concrete can be nothing but a dreary grey. In view of the experience gained in economical construction in the erection of many thousands of houses under the Government scheme, and the more attractive surfaces now available, we look forward to the extensive use of concrete for the construction of small houses when the erection of that class of property is once more an economic proposition.

THE CONCRETE INDUSTRY.

It is not only in the matter of design that concrete needs the most careful consideration at the present time ; that is a problem for the architectural profession, and can, we are sure, be safely left in their hands. But the architect can only put his ideas on to paper and supervise their execution in a general way. It is left to the builder and the operatives actually to carry out the work, and without intelligent and skilful workpeople it is possible—and, indeed, probable—that a fine design may be ruined in execution. In work which depends for its success on the care with which it is carried out, and reinforced concrete depends almost entirely on this factor, it is surprising that so little attention has been paid to the education of the operatives, who at present are often drawn from the ranks of the unskilled or semi-skilled labourers. The intelligent co-operation with the architect by the craftsmen was, to a large extent, responsible for the fine buildings of mediæval times, and the absence of it, which is all too frequent at the present time, is undoubtedly responsible in a large degree for the second-rate work sometimes to be seen nowadays.

The concrete industry has now assumed considerable proportions, and employs a large number of men, which must rapidly increase with the growth of the industry. It is imperative, therefore, that the education of the operatives engaged in the industry should be seriously taken in hand, and that an organised system take the place of the present haphazard methods. The importance of being able to command the services of well-trained workpeople has been realised in other industries, and is to the advantage not only of the employer and employed, but also to the general public who pay for the work. Could not concretors be organised on the lines of the plumbers, who, after passing an examination in their trade at a technical school, are given a certificate of efficiency? In that trade the men who have earned a certificate are registered, and a body of well-trained men is thus formed on which the employers can call with the certain knowledge that those whom they employ are efficient. The plumbers' scheme is controlled jointly by the Worshipful Company of Plumbers, the employers' federation and the trade union, and is, we are assured, working smoothly and to the advantage of all concerned. In America the employees in the concrete industry are a well-trained and well-organised body, and this is reflected in their work.

Although rapid strides have been made in this country recently in the provision of labour-saving machinery, there is no doubt America is ahead of us in this matter also. Machinery for use in concrete work is now well past the experimental stage, and an excellent selection is on view at the Building Trades' Exhibition being held at Olympia from the 11th to the 27th of this month. The more extensive use of this type of plant—concrete mixers, hoists, block-making machines, etc.—would not only cheapen the cost of construction but also result in better work. The mixing and placing of concrete gives no scope for the exercise of craftsmanship in the generally accepted use of that word; the one essential is that the cement, aggregate and water should be mixed exactly according to the specification, and for such work a machine is undoubtedly the best medium. There are also shown at the Exhibition some specimens of coloured concrete blocks, which are sure to arouse interest. A list of the firms connected with the concrete industry who are exhibiting is given in this issue, and next month we hope to give a review of the new devices and materials on view.

AMERICAN CONCRETE HOUSES.

Our American contemporary, *Concrete*, devotes its January number almost entirely to Concrete Houses, some illustrations of which we reproduce with our monthly article on page 256. It is apparent that in America the provision of concrete houses is being pursued with real zest, and many of the same difficulties with which English enthusiasts are beset are now being encountered in America. "We are not especially in need of new methods, more methods, or even, generally speaking, better methods; we need builders who know how to use the methods now available." Our own experience of the countless new methods that were presented to the Housing Department of the Ministry of Health, each patentee thinking to have solved the housing problem, when the real difficulty lay in prejudice against, and unfamiliarity with the usage of concrete, is sufficiently recent to enable us to appreciate the applicability of this passage from our contemporary's leading article to our own country. The article then points out that the time spent in evolving new methods would be better devoted to encouraging the use of, and refining, the methods already in existence. We must quote again, for we cannot improve on these words. "If a builder, feeling 'the urge,' would spend just a quarter of his money investigating and studying the methods that are now available, instead of spending all his money in bringing forth a new system of his own and adding to the Patent Office congestion, we'd soon have more people living in concrete houses, and more contractors making money." This is sound advice with which we most heartily concur. So too we find ourselves in agreement with other opinions, as for example that the efforts of the concrete enthusiast should not be entirely devoted to the production of the cheap house, but he should endeavour to make his appeal to those who want the best, for we are wisely informed "progress is not from the bottom up but from the top down," meaning thereby that every house builder seeks, within the limit of his means, to emulate the best, and seeks inspiration from the class of house above rather than below his own. If, therefore, the better class house is built of concrete, the desire to use this material will percolate downwards.

This brings us to another matter, the importance of which is, we think, more fully realised across the Atlantic than in our own country: good design and good detail. "Make every concrete house architecturally beautiful, and concrete houses will soon dominate the map." If we cannot share in this unqualified optimism for the future, we at least feel convinced that the popularity of concrete will increase only when and as beautiful and attractive houses are produced by its means. That this can be done we have ample evidence. We would, therefore, advise every builder of concrete houses, however small and whether he is building for himself or as a speculation, to seek the services of some young architect with a keenness equalling his own (and such do exist), to design his house. In Minneapolis, U.S.A., there has been organised "The Architects' Small House Service Bureau," which is backed by the American Institute of Architects to meet the need for the provision of good design—in whatever material—for the benefit of every kind of builder. There is room for a similar organisation in this country.

The work of the future would, therefore, seem to be, with us as in America, to concentrate on the methods now at our disposal, to weed out the good from the bad, the simple from the complicated, to organise and educate building operatives, to experiment with new aggregate and new surface treatment, so that imitation masonry—particularly the rock-faced block, for which our contemporary has a righteous contempt—becomes a thing of the past. Finally, let every concrete house be well designed, and well finished, so that its characteristic is quality rather than cheapness. Low cost may well be an incidental advantage of the concrete house, but it must not be the only recommendation. There must be no justification for the present reproaches, so often voiced, of ugliness, dullness, drabness and monotony, for, with good appearance will come that development and extension of the use of concrete which we all desire to see. America is showing us that it can be done.

New Wall, Clonbrook, showing Accretion in Progress.

COAST PRESERVATION IN BRITISH GUIANA.

By HERBERT L. VAHEY.

(Concluded.)

(*The first part of this article appeared in our March Number.*—Ed.)

In the first article, the general condition of the littoral boundary of British Guiana obtaining previous to 1916 was more particularly dealt with, and the steps which it was proposed to take in solving the problems attendant upon the permanent protection of the coast. We are now concerned with the actual progress of the work, and the beneficial results already apparent.

It has already been pointed out that in all coast preservation work carried out under the system selected constructional details vary according to local conditions such as tidal currents, the direction of prevailing winds, etc., but there are other factors of equal importance to be considered when the actual work of designing sea walls, groynes, and other protective measures is taken in hand. Among these must be reckoned the amount of solid shore-building held in suspension (that is to say, carried to and fro by various currents, and partially deposited at slack water), the actual nature of the foreshore upon which the various protective structures had to be erected, and the natural angle, or "angle of repose," of the shore, which, as might be expected, varies with the character of the littoral boundary.

To settle these questions involved very careful consideration, and the accumulation of much relevant information. Ultimately two main points were established: that there was an ample supply of shore-building material held in suspension, or being carried inshore by various currents along the bottom, to be "trapped" by properly designed groynes; and that the character of the foreshore was such as might reasonably be expected to afford secure foundations for the protective works contemplated.

Unfortunately this process of "trapping," to be successful, entailed an enormous amount of laboratory and drawing-office work, which materially retarded the rate of progress of the actual coast protection. Nevertheless, it was only by paying careful attention to minutiæ commonly looked upon as negligible, and previously ignored in earlier attempts, that the engineer responsible for the present scheme could hope to discover the permanent solution of the problem by which he was confronted. Clearly nothing was to be expected from a haphazard distribution of wood or masonry obstructions; all that remained, therefore, was to get to the root of the matter.

Some idea of the difficulties which had to be overcome may be gathered from *Fig.* 1, which shows a rough sea breaking over the old defences at Lusignan. Part of the new sea wall is seen on the right, and over this, it will be noticed, the sea is not breaking. An interesting point is the curve taken by the water ; if this is compared with the elliptical faced sea wall given in the previous article, the controlling idea behind the design of this section is at once apparent.

Fig. 2 illustrates one of the reinforced concrete groynes in process of erection ; when finished the interstices are planked up to the height shown. Most of these groynes were built at right angles to the average shore line, but, on occasion, this was altered and they were placed at an angle. This was the case on the Corentyne Coast where the structure was built diagonally across the foreshore.

Fig. 1. Rough Sea at Lusignan.
Coast Preservation in British Guiana.

As may be imagined on an exposed coast like that of British Guiana the construction of these groynes was attended by the greatest difficulty, as at each high tide the sea swept over the site for several hours, often compelling a cessation of work at a most critical juncture.

Figs. 3 and 4 show very clearly the method employed in dam facing. Each part was built in sections, and the spaces were subsequently filled in with concrete beams. The steps which form such a conspicuous feature of dam facings are used to check the velocity of the back-wash, thus preventing the tendency to "scour," and to afford a convenient place for the deposit of shore-building material.

In regard to *Fig.* 3 it might be well to explain the presence of considerable vegetation on the *seaward* side of the dam, and the absence of a clear sea horizon. This is due to the dam having been built in the rear of a tidal marsh, through which, on occasion, the sea runs with considerable force. To have placed the dam further seaward was impracticable, owing to the difficulty in obtaining a sound foundation, and in carrying on the work in a position affected by the tides. Previous experience has shown that the gradual deposit of material at the foot of the dam wall finally thrusts the marsh seaward, and the luxuriant growth of vegetation rapidly consolidates the position.

In this connection a few remarks upon the important influence and effects of vegetation on the reclamation of low-lying land adjoining the sea may not be out of place.

Very careful investigation has shown that the following tropical trees and plants have special value in retaining accretions already won by an effective

Fig. 2. Partially Constructed Groyne of Reinforced Concrete.
Coast Preservation in British Guiana.

shore protection system: Courida, Black Mangrove, and White Mangrove; their utility being particularly noticeable where the littoral material is of a muddy character. Experiments, however, prove that they are incapable of preventing erosion, though they appreciably retard the rate of inundation and erosion. Their action, which is practically confined to shore areas above the line of breaking waves, is twofold, they tend to slow down the current velocity, thus causing material which would otherwise be borne away to be deposited, and they supply seeds and decayed material which tend to increase growth. Indirectly, since the branches afford resting places for birds, etc., and the roots a habitation for marine animals, they add material to the foreshore.

In *Fig.* 5 the extraordinarily beneficial effect of vegetation is remarkable. Here the growth, which is exceedingly rapid in British Guiana, has already consolidated ground that was formerly tidal marsh, so that a canal of "brackish" water has been formed at the foot of the sea wall. Naturally when the accretion has reached this stage the possibility of erosion is practically negligible. The variation in the curve at the top of the wall is worthy of notice : in this case it is approximately segmental and only slightly elliptical.

The formation of these canals is not confined to the front of the sea wall. *Fig.* 6 shows a wide channel at the rear. In such cases, however, the water is not the direct result of tidal or wave action, but is derived from the drainage of back lands—the water being pumped from the various estates and plantations—to be released by sluices at convenient states of the tide.

Although this system of drainage was not of itself objectionable, the manner in which it was carried out, and the primitive methods adopted, constituted, in

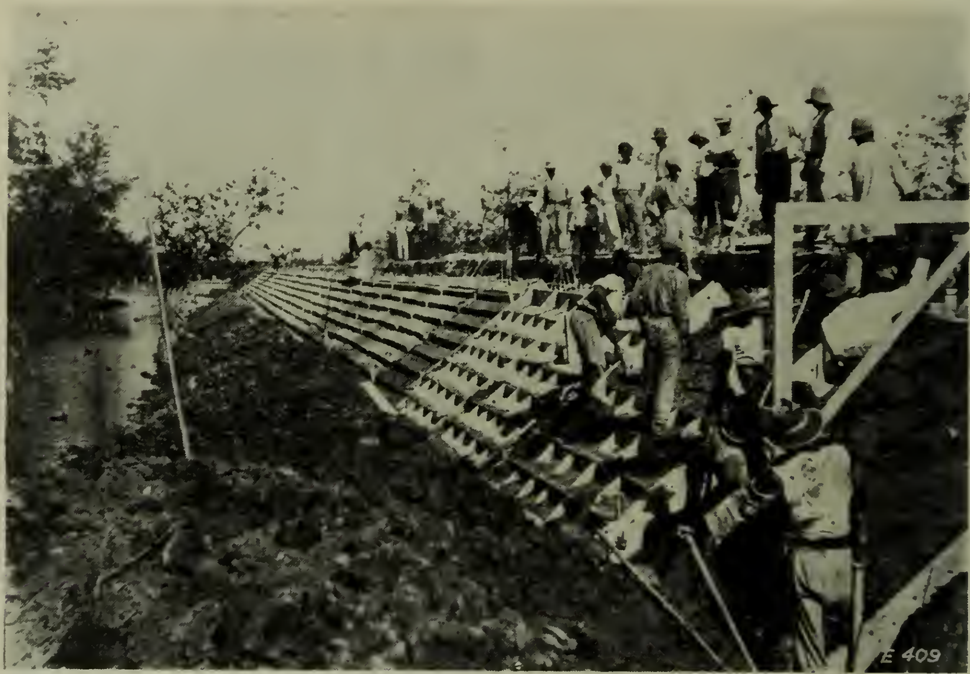

Fig. 3. Dam Facing Annandale (E. Coast).
Coast Preservation in British Guiana.

the opinion of the consulting engineer, a distinct menace to the health of the community, and more especially those who dwelt on the front-lands.

However, to deal with the matter basically would have involved the Government of British Guiana in a heavy outlay, and it was decided to temporise, and pave the way for the installation of a more scientific system, by placing properly constructed reinforced concrete sluices in line with the new sea-walls, the ultimate aim being to erect pumping stations contiguous to the new sluices, whereby the discharge of water from an adequately constructed reservoir canal might be controlled.

By this means the tendency of the sluice run or outlet to silt up would be overcome. It would not be necessary to keep the pumps in continuous action, as, for the most part, gravity drainage would be sufficient, but they would be required periodically to " flush-out " the run, and maintain thereby a clear overshore flow.

We must now turn to the results already achieved, up to the commencement of 1920.

In his report to the Government, dated 6th November, 1917, the engineer responsible for the work was able to state that on the Lusignan, Beterverwagting, and the Clonbrook Grove sections of the East Coast "the condition of the foreshore is already improving at a rate beyond my most sanguine expectations. In front of the Lusignan sea-wall the foreshore has built up an average of 3 ft. 6 in., and in what were formerly the most eroded portions to a height of from 5 to 6 ft." (This accretion was built up in just over a year from the commencement of the work.)

The report continues: "On the Clonbrook section, where in the spring of 1917 very rapid erosion was taking place, and where a great part of the public road was washed away and the rest of it threatened with entire destruction, we now find that the foreshore is built up from *two to three feet above* the roadway." *

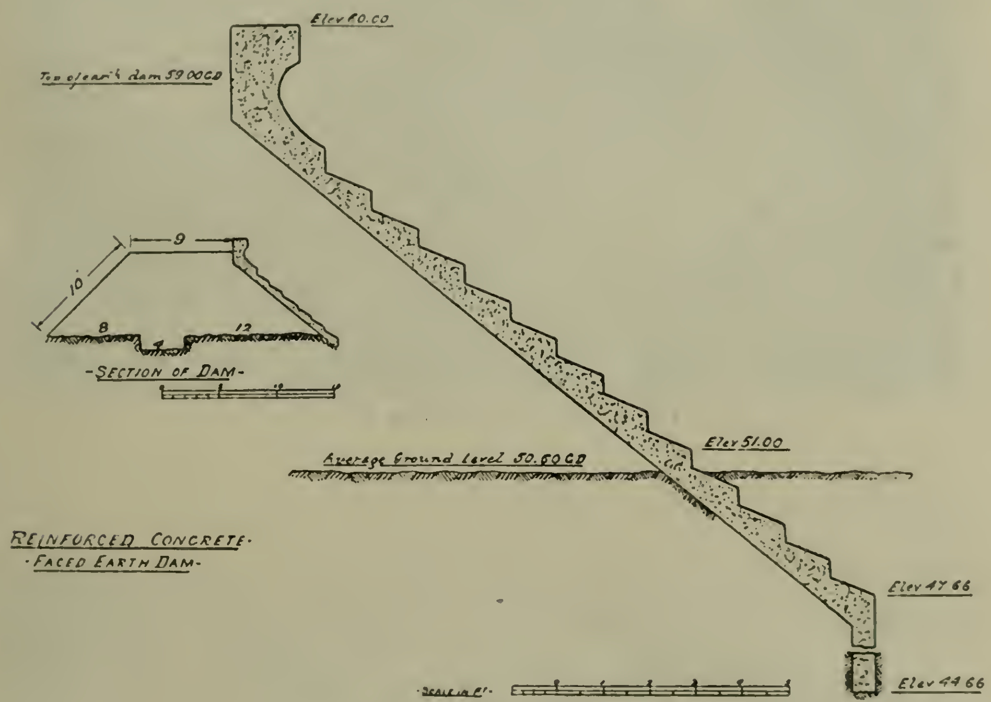

Fig. 4.
COAST PRESERVATION IN BRITISH GUIANA.

Reporting to the Officer Administrating the Government in May, 1919, the consulting engineer stated that "the beneficial effects have far exceeded what I anticipated, and I know of no foreshore, in England or elsewhere, where groynes have so rapidly accumulated material as they have done on the East and West Coasts."

Fig. 8 and the illustration at the top of this article show portions of the sea-wall at Clonbrook, the former shortly after the work was completed, and the latter about the time Mr. Case made his first report to the Government (6th November, 1917). Although the rate of accretion varied considerably in accordance with local conditions, it will be seen in the illustration above that a maximum of four steps is exposed (there being eight altogether, as shown in *Fig.* 8). It may be mentioned that the "vanishing point" of the wall in the later photograph corresponds with the angle shown in the earlier. The headland across the bay may be clearly traced in both.

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* The italics are ours.—ED. CONCRETE.

In sending in his final report (Nov., 1919) to the Government on the effects of the system on the East and West Coasts of Demerara, Mr. Case stated: "I am of opinion that the general situation may be considered very satisfactory.

Fig. 5. Sea Wall at Rear of Tidal Marsh.

Fig. 6. Clonbrook Wall (Looking E. from Road).
COAST PRESERVATION IN BRITISH GUIANA.

Wherever there is a clear foreshore (that is where old sea defences have been removed) the groynes are doing excellent work in building up the foreshore, and I venture to state that there is every indication that the work when completed will be entirely successful in protecting the coast."

This prediction, we may add, has been amply fulfilled, and dangerous erosion, or anything like serious sea encroachment on any foreshore lands dealt with in the manner we have described, has been entirely prevented.

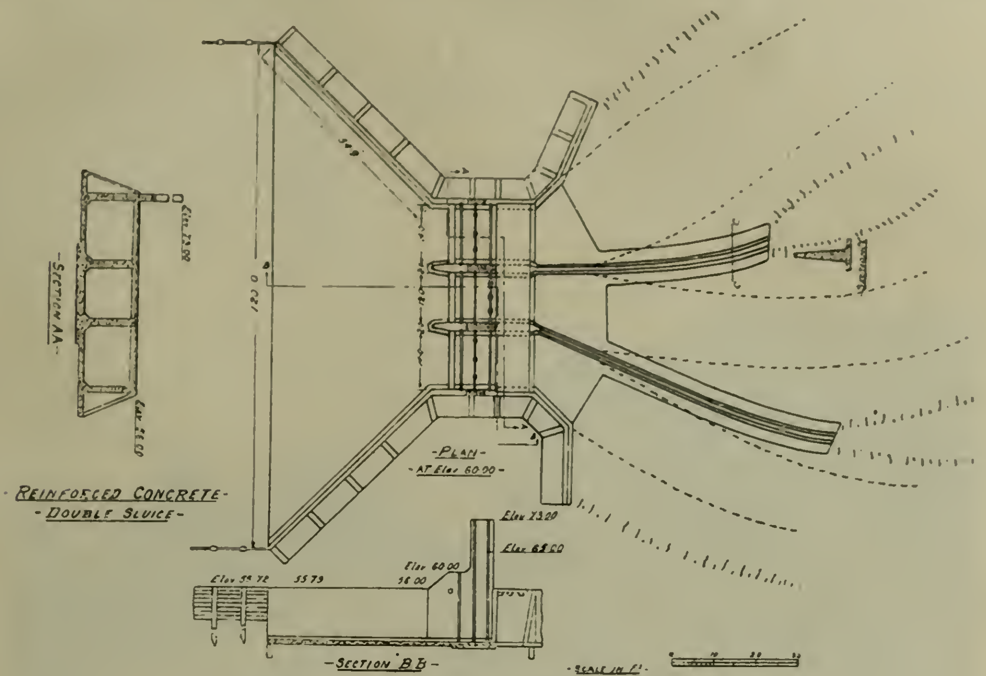


Fig. 7. Reinforced Concrete Double Sluice.

Fig. 8. New Wall, Clonbrook.
Coast Preservation in British Guiana.

An excellent idea of the remarkable effects produced in water-logged areas or localities occupied by tidal marshes may be gained from a glance at *Fig.* 9, in which, it will be noticed, the steps are already covered, and the land, well clothed with vegetation, thoroughly compacted and consolidated. The straw-like material at the base is composed of dead grass, leaves, twigs and light, floating vegetable matter. The fact that it has been retained in this position is in itself evidence of the efficacy of this type of sea-wall design.

Such then, in brief, is the history of Coastal Protection and Reclamation of the sea boundaries of British Guiana, an achievement which marks yet another step forward in the conquest of nature and natural forces by man. The consulting engineer, Mr. Case, is not only to be congratulated upon having successfully completed a difficult undertaking, which is the largest of its kind in the world, but in laying the foundation for another scheme, which, if carried out, will go far to improve the health and increase the wealth of those living in this fertile and prosperous Colony.

Fig. 9. Sea Wall, Moss Rapid (Looking East).
COAST PRESERVATION IN BRITISH GUIANA.

So far nothing has been decided, but a system of drainage such as we have briefly indicated is the natural outcome and logical consequence of efficient foreshore preservation.

In conclusion the author desires to thank Mr. Case for his courtesy in furnishing details and photographs of his most interesting work in this part of the world, which cannot fail to interest engineers and all who are interested in the universal application of reinforced concrete to the solution of constructional problems which have a bearing upon the health and prosperity of the British Empire.

PROBLEMS IN THE THEORY OF CONSTRUCTION.

SOME PROBLEMS IN DEFLECTION OF BEAMS.

By EWART S. ANDREWS, B.Sc.Eng.

We give below the derivation of formulæ for the deflection of beams for two cases that are not usually dealt with in the text-books; in order to suit the needs of students who find it simpler to follow calculations based upon reasoning not involving the methods of the integral calculus, we give, after the orthodox mathematical treatment, one based upon the graphical conceptions following Mohr's Theorem.

Case I. Beam Supported at One End and Cantilevered at the other, a Point Load being Applied on the Cantilevered End.

Mathematical Treatment.—Fig. 1 represents the loading condition, the bending-moment diagram and the deflected form of the beam.

Now considering a point P on the beam between the supports and at distance x from the right support R, we have reaction at $R=R_R=\frac{Wa}{l}$.

$$\therefore \text{ Bending moment at } P=B=R_R\times x=\frac{Wax}{l} \quad \ldots \quad (i)$$

$\therefore$ Applying the usual mathematical relation to determine the deflection y at P, assuming that the beam is of constant section, we have

$$EI\frac{d^2y}{dx^2}=B=\frac{Wax}{l} \quad \ldots \quad (ii)$$

Integrating once, we have

$$EI\frac{dy}{dx}=\frac{Wax^2}{2l}+C_1 \quad \ldots \quad (iii)$$

where $\frac{dy}{dx}$ denotes the slope of the tangent to the beam at P.

Integrating again, we have

$$EIy=\frac{Wax^3}{6l}+C_1x+C_2 \quad \ldots \quad (iv)$$

when $x=0$, $y=0$.

$\therefore$ from eqn. (iv) C_2 must $=0$

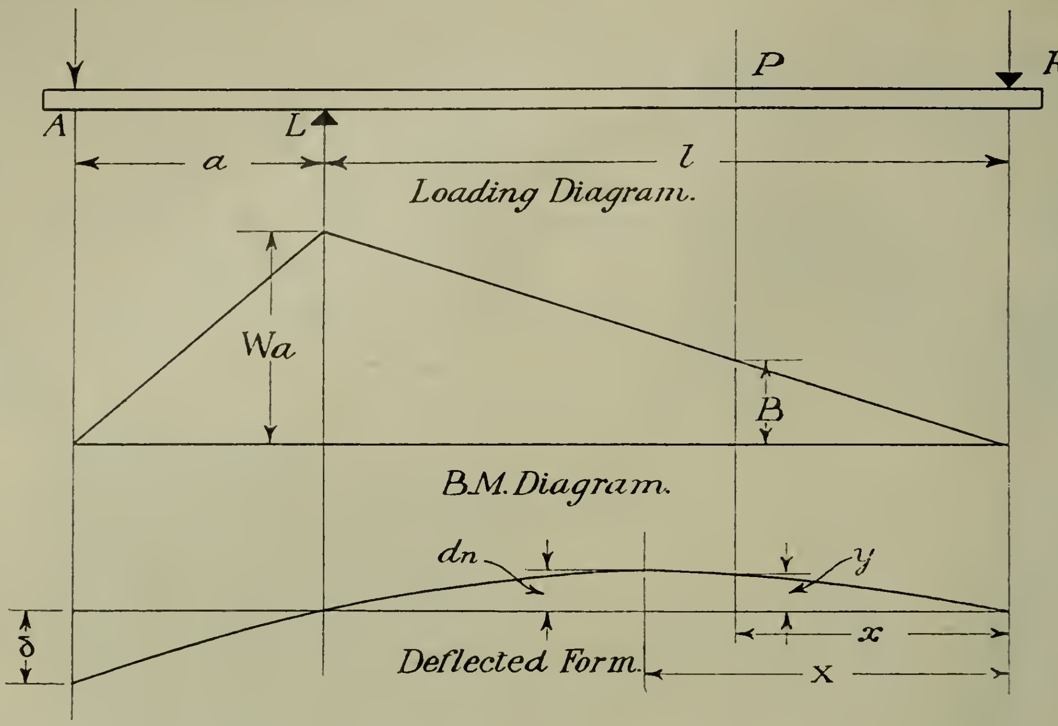


Figure 1.

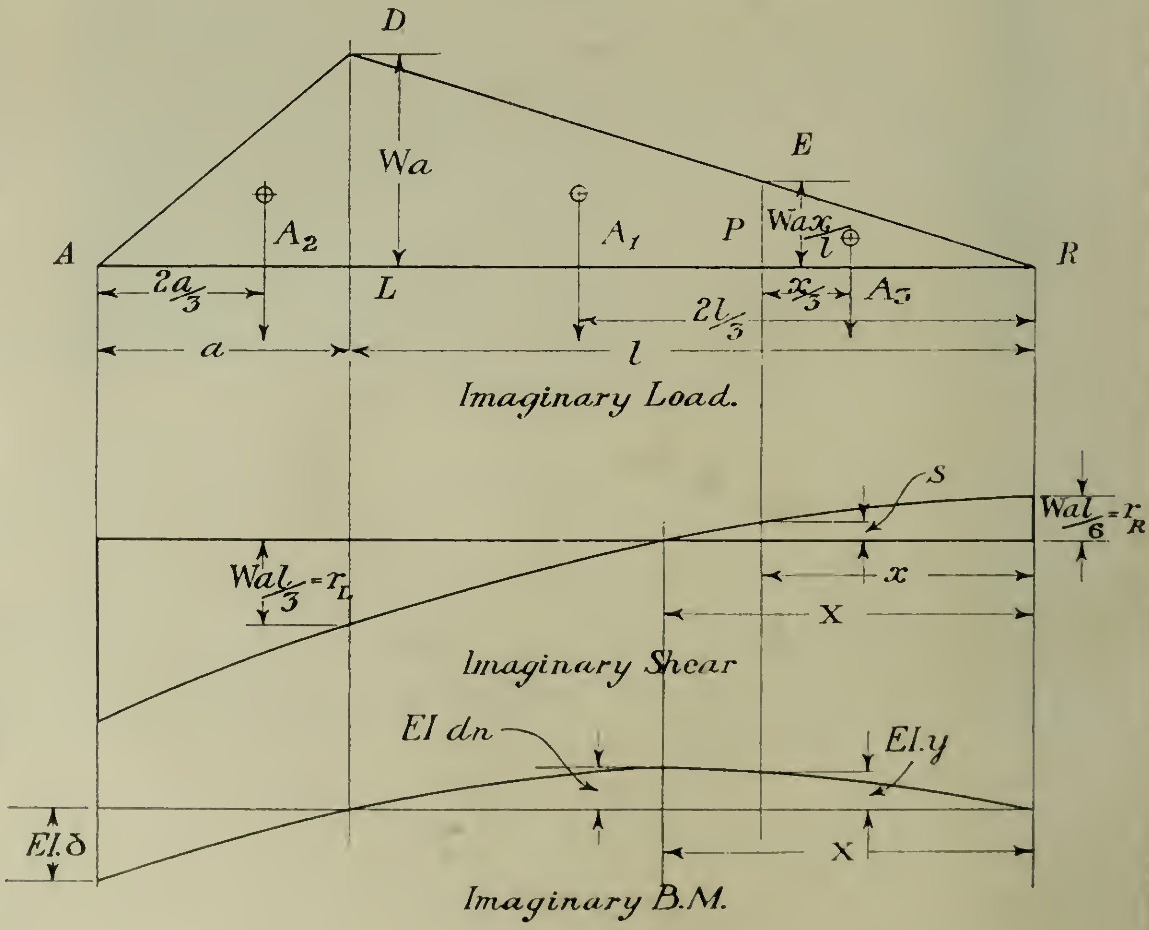


Figure 2.

Again, when $x=l$, $y=0$.

$$\therefore \text{ from } =n. (iv)\ 0=\frac{Wal^3}{6l}+C_1 l+0$$

$$\therefore C_1=-\frac{Wal}{6} \quad \ldots \quad (v)$$

$=n.$ (iv) therefore becomes

$$EIy=\frac{Wax^3}{6l}-\frac{Walx}{6}$$

$$=\frac{Wa}{6}\left(\frac{x^3}{l}-lx\right) \quad \ldots \quad (vi)$$

In order to calculate the maximum deflection d_n we must find the value of x at which the slope of the beam is zero.

From $=n.$ (iii) we then have

$$0=\frac{Wax^2}{2l}-\frac{Wal}{6}$$

$$\text{i.e. } x^2=\frac{l^2}{3}$$

$$\text{or } x=\cdot 577l \quad \ldots \quad (vii)$$

Then putting this value in $=n.$ (vi) we get

$$EId_n=\frac{Wa}{6}\left(\frac{l^2}{3}\frac{\cdot 577l}{l}-\cdot 577l^2\right)$$

$$=-\frac{Wal^2\times\cdot 577}{6}\left(1-\tfrac{1}{3}\right)$$

$$=-\frac{Wal^2\times\cdot 57}{9}$$

$$=-\cdot 064Wal^2 \quad \ldots \quad (viii)$$

[The $-$ve sign indicates that the deflection is upwards.]

Now suppose we require to find the deflection δ at the free end A.

This will clearly be equal to the deflection of a cantilever of length a with load W at end plus a times the slope of the beam at L,

$$\text{i.e. } \delta=\frac{Wa^3}{3EI}+a.\frac{dy}{dx}.$$

Now putting $x=l$ in equation (iii), we have

$$EI\frac{dy}{dx}=\frac{Wal^2}{2l}-\frac{Wal}{6}$$

$$=\frac{Wal}{2}\left(1-\tfrac{1}{3}\right)$$

$$\therefore \frac{dy}{dx}=\frac{Wal}{3EI}$$

$$\therefore \delta=\frac{Wa^3}{3EI}+\frac{Wa^2l}{3EI}$$

$$=\frac{Wa^2}{3EI}(a+l) \quad \ldots \quad (ix)$$

Graphical Treatment.—Treating the bending moment diagram as an imaginary load diagram, the corresponding imaginary shear diagram at any point gives EI times the slope of the beam, and the corresponding imaginary bending moment diagram gives EI times the deflection of the beam.

We will bear in mind the fact that in applying this theorem to the case of a cantilever we have to regard as the free end of the imaginary beam that at which the slope and deflection are zero, i.e. we regard the fixed end as free and the free end as fixed.

We then have the imaginary load, shear and B.M. diagrams shown in *Fig.* 2.

Taking first the span LR, we have

$$\text{Total load} = \text{area of } \Delta\, DLR = A_1 = \frac{Wal}{2}$$

$$\text{Imaginary shear at } R = r_R = \frac{A_1}{3} = \frac{Wal}{6}$$

$$\text{,, \quad ,, \quad } L = r_L = \frac{2A_1}{3} = \frac{Wal}{3}$$

$$\text{Imaginary B.M. at } P = EI.y$$

$$= r_R.x - \text{area } \Delta\ EPR.\frac{x}{3}$$

$$= \frac{Walx}{6} - \frac{Wax}{l}.\frac{x}{2}.\frac{x}{3}$$

$$= \frac{Wax}{6}\left(l - \frac{x^2}{l}\right) \quad \ldots\ldots \quad (x)$$

Point of maximum imaginary B.M. = point of zero imaginary shear. If shear is zero at value of $x = X$, area corresponding to $\Delta\ EPR$ will equal r_R.

$$\text{i.e. } \frac{WaX}{l}.\frac{X}{2} = \frac{Wal}{6}$$

$$X^2 = \frac{l^2}{3},\ X = \cdot577l \quad \ldots\ldots \quad (xi)$$

Putting this value in *n.* (x) we have

$$EI.d_n = \frac{Wa \times \cdot577l}{6}\left(l - \frac{l^2}{3l}\right)$$

$$= \cdot064Wal^2$$

$$d_n = \frac{\cdot064Wal^2}{EI} \quad \ldots\ldots \quad (xii)$$

Next take imaginary span LA which we assume fixed at A and free at L; the imaginary load is the point load at L equal to the imaginary reaction from the span RL, together with the loading given by the $\Delta\ DLA$.

We then have:

Imaginary B.M. at $A = EI.\delta$

$$= r_L.a + \text{area } \Delta DLA.\frac{2a}{3}$$

$$= \frac{Wal}{3}.a + Wa.\frac{a}{2}.\frac{2a}{3}$$

$$= \frac{Wa^2}{3}(l+a)$$

$$\therefore\ \delta = \frac{Wa^2}{3EI}(l+a) \quad \dots\dots\dots \quad (xiii)$$

This agrees with the result obtained in $=n$ (*ix*) by the mathematical treatment.

CASE II. UNIFORMLY LOADED BEAM SUPPORTED AT ONE END AND FIXED AT THE OTHER.

The deflection in this case will of course be the same as that for a continuous beam of two equal spans each uniformly loaded with a load of the same intensity.

Mathematical Treatment.—In this case we assume the well-known result that the reaction at the supported end is $\frac{3}{8}$ of the total load.

Then considering a point P at distance x from the free end L, *Fig.* 3, we have

$$B = EI\frac{dy^2}{dx^2} = \frac{3Wl}{8}.x - \frac{wx^2}{2} \quad \dots\dots\dots \quad (A)$$

$\therefore$ Integrating once, we have

$$EI\frac{dy}{dx} = \frac{3wlx^2}{16} - \frac{wx^3}{6} + C_1 \quad \dots\dots\dots \quad (B)$$

And integrating again, we have

$$EIy = \frac{wlx^3}{16} - \frac{wx^4}{24} + C_1x + C_2 \quad \dots\dots\dots \quad (C)$$

Now $y=0$ when $x=0$

$\therefore\ C_2 = 0$

Also $y=0$ when $x=l$

$$\therefore \text{ in } (C)\ \frac{wl^4}{16} - \frac{wl^4}{24} + C_1l = 0$$

$$\therefore C_1 = -\frac{wl^3}{16} + \frac{wl^3}{24}$$

$$= -\frac{wl^3}{48} \quad \dots\dots\dots \quad (D)$$

Again $\frac{dy}{dx}$ should be zero when $x=l$

$$\therefore \text{ in } (B)\ \frac{3wl^3}{16} - \frac{wl^3}{6} - \frac{wl^3}{48} \text{ should } = \text{ zero.}$$

$$\therefore\ \frac{wl^3}{48}(9-8-1) \text{ should } = \text{ zero.}$$

This is the case.

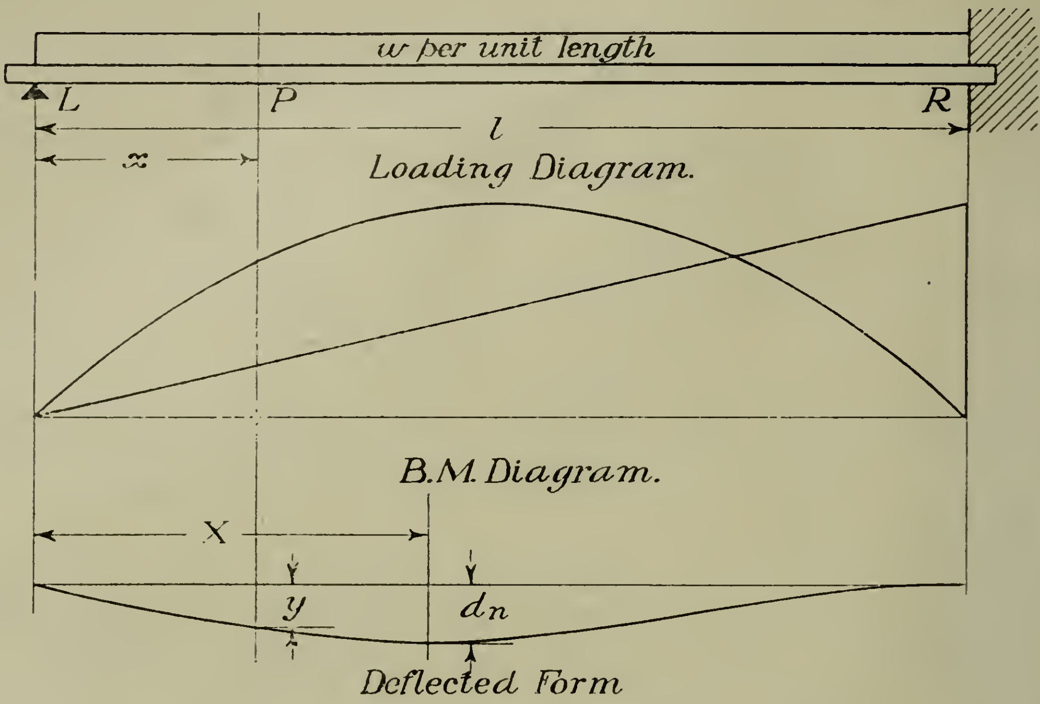


Figure 3.

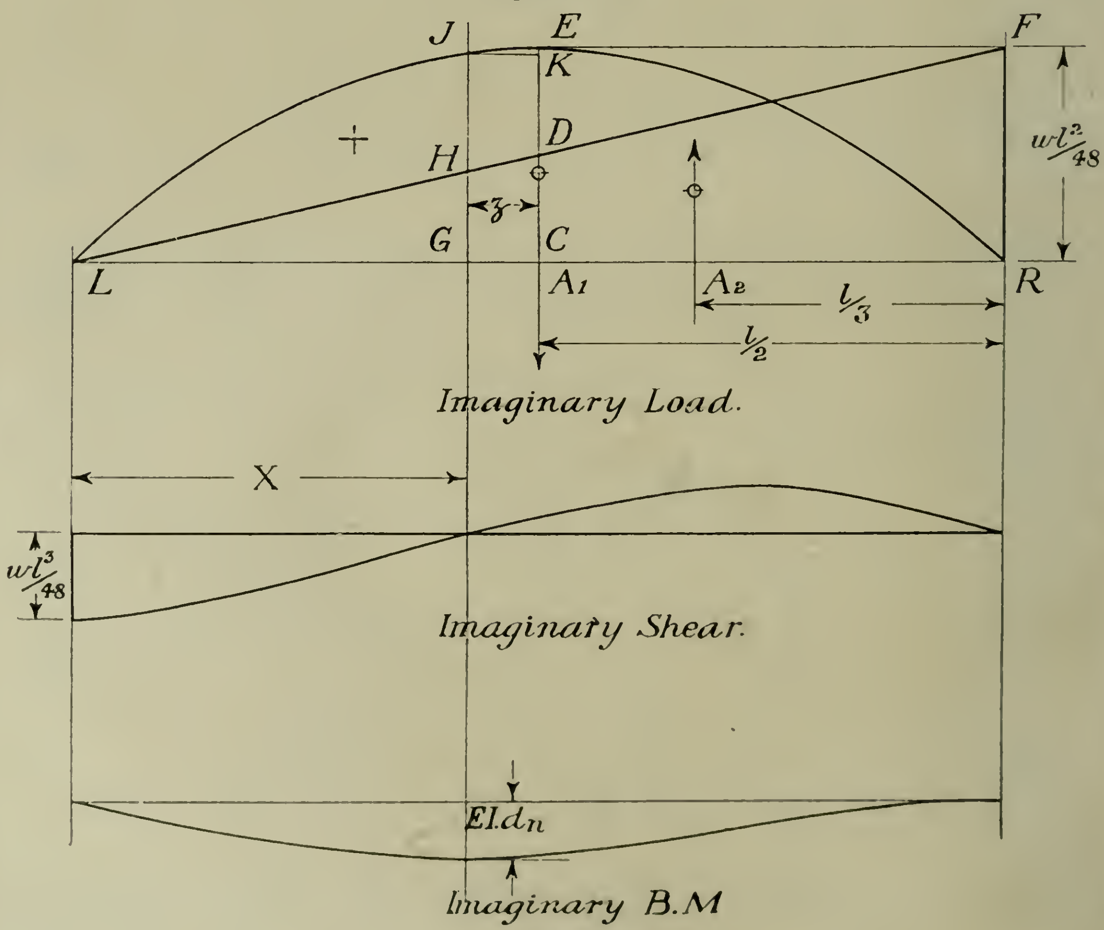


Figure 4.

Our equation for the deflected form of the beam therefore becomes :

$$EIy=\frac{wlx^3}{16}-\frac{wx^4}{24}-\frac{wl^3x}{48}$$

To find the maximum deflection we have now to value X at which $\frac{dy}{dx}=0$.

$$\therefore \text{ from } (B)\ \frac{3wlx^2}{16}-\frac{wx^3}{6}-\frac{wl^3x}{48}=0 \quad \ldots \quad (E)$$

$$\text{i.e. } 9lx^2-8x^3-l^3=0$$

$$\text{i.e. } 8x^3-9lx^2+l^3=0 \quad \ldots \quad (F)$$

$$(x-l)\ (8x^2-lx-l^2)=0.$$

The real solution of the second quadratic factor gives $x=\cdot422l$, the solution of the first factor giving the value $x=l$ already obvious from the conditions of the problem.

We therefore see that

$$X=\cdot422l \quad \ldots \quad (G)$$

Putting this value in equation (E) for the deflection at any point, we have

$$EI.d_n=\frac{wl}{16}\times(\cdot422l)^3-\frac{w\times(\cdot422l)^4}{24}-\frac{wl^3\times\cdot422l}{48}$$

$$=\cdot0054wl^4$$

$$\therefore d_n=\frac{\cdot0054wl^4}{EI} \quad \ldots \quad (H)$$

or if the total load on the span $=wl=W$

$$d_n=\frac{\cdot0054Wl^3}{EI}=\frac{Wl^3}{185EI} \quad \ldots \quad (I)$$

The corresponding deflection for the same span simply supported at each end is $\frac{5Wl^3}{384EI}=\frac{Wl^3}{76\cdot8EI.}$

$\therefore$ *The deflection in the case under consideration is approximately* ·41 *times that of the ordinary simply supported beam.*

Graphical Consideration.—The imaginary load diagram in this case, which corresponds to the bending moment diagram of the actual beam, consists of a positive parabola LER (*Fig.* 4), and a negative triangle LFR, the height of each being $\frac{wl^2}{8}$.

The area of the parabola $=A_1=\frac{2}{3}\frac{wl^2}{8}.l=\frac{wl^3}{12}$

" " Δ $=A_2=-\frac{wl^2}{8}\cdot\frac{l}{2}=-\frac{wl^3}{16}.$

The imaginary reaction at L is obtained by taking moments about R, then

$$r_L.l=-\frac{wl^3}{16}\cdot\frac{l}{3}+\frac{wl^3}{12}\cdot\frac{l}{2}$$

$$\therefore r_L=\frac{wl^3}{48} \quad \ldots \quad (J)$$

This will be regarded as negative, as the beam slopes downwards at L, and the imaginary shear comes as shown. The imaginary shear at the other end will be equal to $A_1+A_2-r_L=\frac{wl^3}{48}-\frac{wl^3}{48}=0$; this should be the case since the beam is horizontal at R.

To find the maximum imaginary B.M. we have first to find the point G of zero imaginary shear.

This occurs when $r_L=\text{area } LGJ-\text{area } LGH$ . . . . (K)

We will first calculate the area LGJ.

Now area $LGJ=\text{area } LCE-\text{area } JGCE$

$=\text{area } LCE-\text{area } JGCK-\text{area } JKE.$

Of these, the area $LCE=\frac{A_1}{2}=\frac{wl^3}{24}$

Also by the properties of the parabola, if $GC=JK=z$

$$\frac{EK}{EC}=\frac{z^2}{\left(\frac{l}{2}\right)^2}=\frac{4z^2}{l^2}$$

$$\text{i.e. } EK=\frac{4z^2}{l^2}\cdot\frac{wl^2}{8}=\frac{wz^2}{2}$$

$$\therefore \text{ Area } JKE=\frac{2}{3}\,EK.JK$$

$$=\frac{2}{3}\cdot\frac{wz^2}{2}\cdot z$$

$$=\frac{wz^3}{3}$$

$$\text{And area } JGCK=z\times Kc=z\times\frac{wl^2}{8}-\frac{wz^2}{2}$$

$$=\frac{wz}{8}(l^2-4z^2)$$

Further the area LGH is equal to $\frac{1}{2}$ $LG.GH$

$$=\frac{x}{2}\cdot\frac{x}{l}\cdot\frac{wl^2}{8}=\frac{wlx^2}{16}$$

$\therefore$ putting the above values into $=n.$ (K) we have

$$\frac{wl^3}{48}=\frac{wl^2}{24}-\frac{wz}{8}(l^2-4z^2)-\frac{wz^3}{3}-\frac{wlx^2}{16}$$

$\therefore$ dividing through by $\frac{w}{48}$ we have

$$l^3=2l^3-6l^2z+24z^3-16z^3-3lx^2$$

or $8z^3-6l^2z-3lx^2+l^3=0$ . . . . $(L$

putting $z=\left(\frac{l}{2}-x\right)$ this reduces to

$8x^3-9lx^2+l^3=0$ . . . . (F)

This is the equation (F) obtained by the mathematical treatment and, as already explained, gives the result

$$x = \cdot 422l \qquad (G)$$

$$\text{i.e. } z = \cdot 078l$$

$$\therefore\ EK = \frac{wz^2}{2} = \cdot 00304wl^2$$

$$KC = \cdot 125wl^2 - \cdot 00304wl^2 = \cdot 122wl^2$$

$$HG = \frac{\cdot 422wl^2}{8} = \cdot 05275wl^2$$

To calculate the maximum deflection we require to find the imaginary bending moment about the point G.

Then we have

$$\frac{d_n}{E} = r_L.x - \text{moment of } LJG + \text{moment of } \Delta\ LGH$$

$$r_L.x = \frac{wl^3}{48} \times \cdot 422l = \cdot 008792wl^4$$

$$\text{moment of } \Delta\ LGH = HG.\frac{x}{2}.\frac{x}{3}$$

$$= \frac{\cdot 05275wl^2 \times \cdot 422^2 l^2}{6}$$

$$= \cdot 001566wl^4$$

$$\text{moment of } LJG = \text{moment of } LCE - \text{moment of } JGCK - \text{moment of } JEK$$

$$= \frac{2}{3}.\frac{l}{2}.\frac{wl^2}{8}\left(x - \frac{5l}{16}\right) - \left(-KC.z.\frac{z}{2}\right) - \left(\frac{2}{3}EK.z.\frac{5z}{8}\right)$$

$$= (\cdot 004583 + \cdot 000371 + \cdot 000008)wl^4$$

$$= \cdot 004962wl^4$$

$$\therefore\ \frac{dn}{EI} = (\cdot 008792 + \cdot 001566 - \cdot 004962)wl^4$$

$$= \cdot 0054wl^4 \text{ approx.}$$

$$\therefore\ dn = \frac{\cdot 0054wl^4}{EI}$$

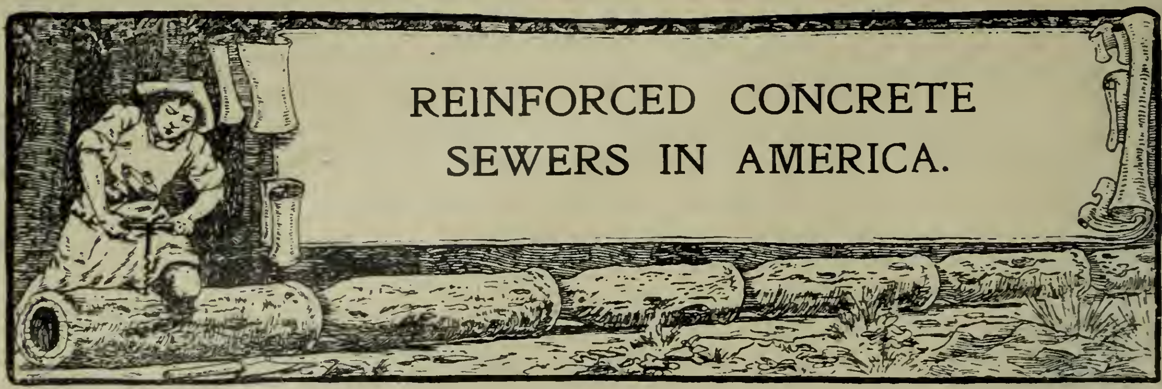
$$= \frac{wl^4}{185EI}$$

This agrees with the value obtained by the mathematical analysis.

MEMORANDUM.

Our Frontispiece.—Our frontispiece shows a reinforced concrete caisson, claimed to be the largest yet built in the British Isles, which was recently launched in connection with some improvements at the Alexandra Basin, Dublin. This caisson is one of a series to be used in the construction of a quay wall. The foundations and lower courses were erected on land and launched. Whilst afloat its outer walls will be built upwards, the caisson itself gradually sinking by ballasting until its depositing depth has been reached, when it will be towed to its final position and sunk. The superstructure will then be built upon the upper portion of the deposited caisson exposed above the surface of the water. When ready for depositing in place the caisson will weigh approximately 3,000 tons.

The caisson is the design of Mr. J. Mallagh, Engineer to the Dublin Dock Board.



REINFORCED CONCRETE SEWERS IN AMERICA.

By Prof. E. R. MATTHEWS, Assoc.M.Inst.C.E., F.R.S. (Ed.) (Drainage Engineer).

For several years the author has recommended the use of reinforced concrete in the construction of sewers of large section, and he has pointed out—

(1) That by using this material a saving of about 10 per cent. can be effected.

(2) That the life of the structure is far greater if of reinforced concrete than it would be if of brick, and

(3) That it can be constructed *in situ*, and so planned that it can take any particular curve, or unusual shape.

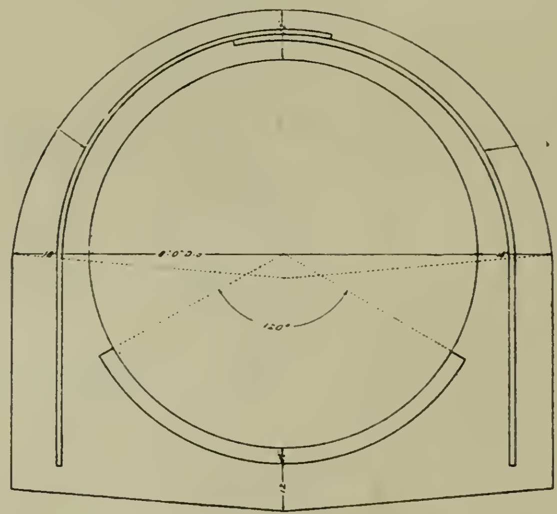


Fig. 1. Stickfoot Branch Trunk-Section showing Reinforcement.

The author would add to the above the following reasons why this material should be used :—

(*a*) Because by using reinforcement the walls of sewers may be reduced in thickness to meet the various stresses, especially those that occur during abnormal storms, when the sewer may be under pressure.

(*b*) That where the sewer has to be constructed in bad ground, or water-logged or swampy ground, the best material to use is undoubtedly reinforced concrete.

(*c*) Because of its watertightness, strength, and adaptability to all shapes of construction. It cannot be surpassed for pile foundation work, and its construction is easy.

(*d*) Deterioration cannot take place, if good materials are used.

The Chief Engineer to the Department of Public Works, Philadelphia, U.S.A., informs the author that "no deterioration has been observed in the concrete and reinforced concrete sewers in that city in twenty years' service on the combined system (sewage and storm water), but he has had no experience, he says, in the use of concrete for conduits conveying concentrated sewage only."

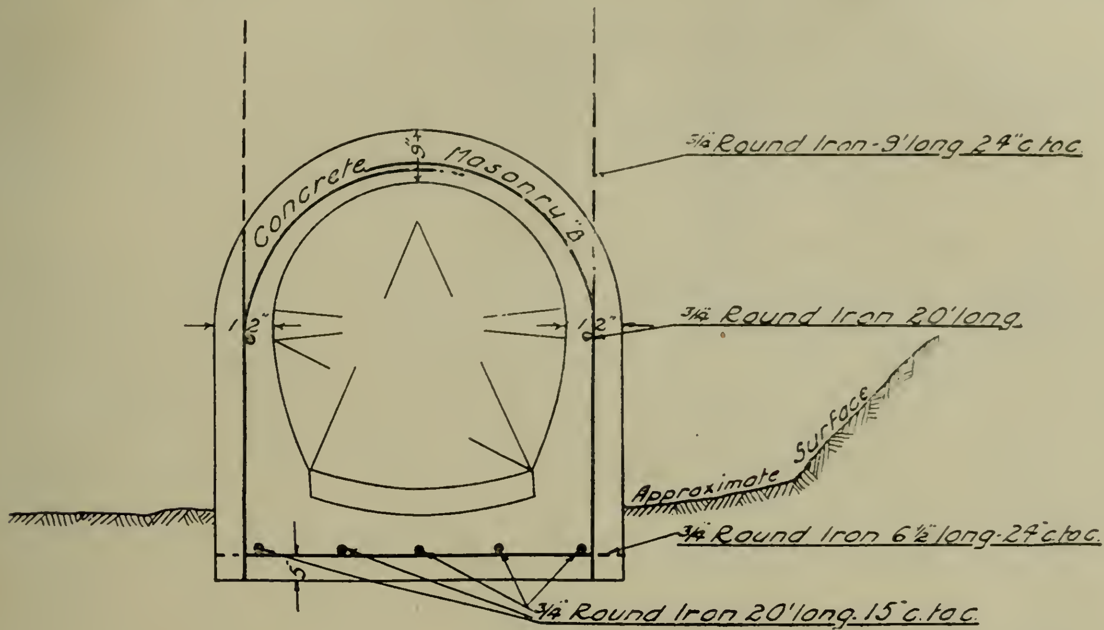


FIG. 2.

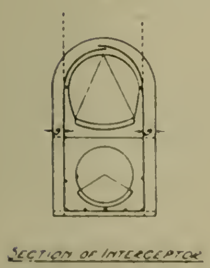


FIG. 5.

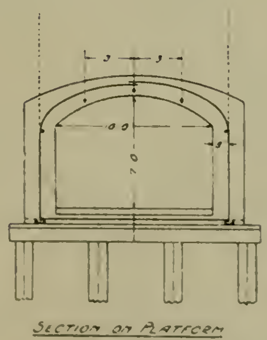


FIG. 3.

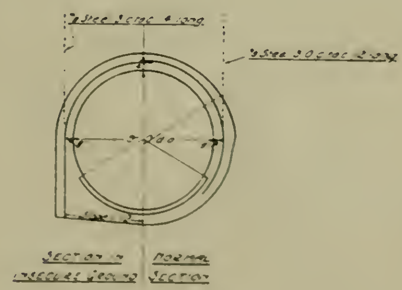


FIG. 4.

OUTLET—SCAGGS BRANCH TRUNK SEWER. SECTION SHOWING STEEL REINFORCEMENT.

Some particulars will now be given of large reinforced concrete sewers constructed in various American cities.

REINFORCED CONCRETE SEWERS IN WASHINGTON.

Figs. 1 to 5 (inclusive) illustrate five types of reinforced concrete sewers which have been constructed in Washington, U.S.A. These sewers were built under difficult circumstances, but chiefly where the fill was excessive, and the base under it unstable.

In the Scaggs Branch example (*Fig.* 3) the sewer section was depressed in height, and built on a platform crossing a marshy flat ; a section of the same sewer is shown in *Fig.* 4, where the ground was both normal and insecure. The Rock Creek Main Interceptor (see *Fig.* 5) shows reinforcement where the fill over the sewer was very excessive.

The author recommends the construction as in *Fig.* 1 of a 4½-in. Vitrified Brick Invert to all reinforced concrete sewers which are intended to take sewage, to prevent wearing of the invert, and to obviate any detrimental effect in the way of chemical action of the sewage on the concrete (see *Fig.* 1).

"*Stickfoot Branch Trunk.*"—*Fig.* 1 represents a reinforced concrete circular sewer constructed in Washington; it is 8 ft. in diameter (inside measurement); is reinforced by the insertion of ¾-in. cold twisted steel bars 11 ft. long, and at 30 in. centres. The thickness of the walls at springing is 18 in., and at the crown 12 in.

The minimum depth of concrete under the vitrified-brick invert is 12 in.

This sewer is on a "combined" system.

"*Anacostia Main Interceptor.*"—This is illustrated in *Fig.* 2, which shows in detail the reinforcement. The sewer has a flat base, with 4½-in. vitrified-brick invert; it is chiefly above ground. The walls are 12 in. thick at springing, and 9 in. at crown. The inside measurements are: height 4 ft. 9 in., width at springing 4 ft. 6 in. Depth of concrete under centre of invert, 12 in. The reinforcement consists of ¾-in. round iron bars 20 ft. long, and ¾ in. round iron bars (vertical) 9 ft. long, and at 24-in. centres. The bars overlap where they meet 12 in.

In the foundation slab there are also ¾-in. round iron bars, but these are placed at 15-in. centres.

"*Scaggs Branch Trunk Sewer Outlet.*"—This is a more unusual type of construction. It has been built on a platform as illustrated in *Fig.* 3; it is 10 ft. wide at springing with vertical walls and is 7 ft. deep, the walls being 16 in. The reinforcement consists of ⅞-in. steel bars.

Fig. 4 represents two sewers leading to this outlet sewer; these are shown in one section, the "Normal" section, and the "Insecure ground" section. The former shows a circular reinforced concrete sewer 9 ft. diameter with walls at springing 16 in. in thickness, and 8 in. at crown. The reinforcement consists of ⅞-in. steel bars. The invert is lined with bricks.

On the "Insecure ground" section it will be seen that the reinforced concrete foundation slab is flat and not curved as in the "normal" section, otherwise the dimensions are the same.

Fig. 5 shows two sewers built one above the other; the bottom one is 3 ft. 6 in. diameter, the top one 4 ft. 6 in. × 4 ft. 6 in., all built in reinforced concrete. The vertical walls are 9 in. in thickness, and the reinforcement consists of ¾-in. steel rods. The structure has a flat bottom, and the inverts are brick-lined.

REINFORCED CONCRETE SEWERS IN CLEVELAND.

City of Cleveland, U.S.A.—The Department of Public Service, Division of Engineering and Construction, have during the past few years constructed various large-section sewers in reinforced concrete. These are in the nature of culverts, and are illustrated in *Figs.* 6 to 11. They were built to enclose a natural watercourse, and, in addition, are used as storm-water sewers in the various districts.

They have been built for the most part following the bed of a creek, and are designed to be filled in with a considerable depth of fill; hence it has been found economical to use the reinforced box-section type.

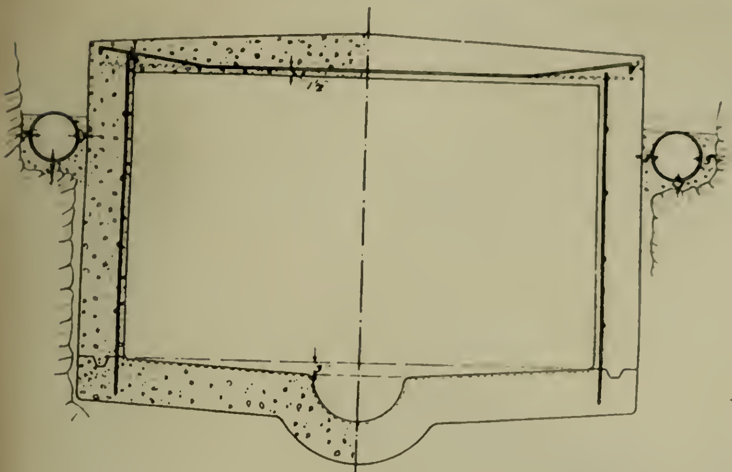


FIG. 6.

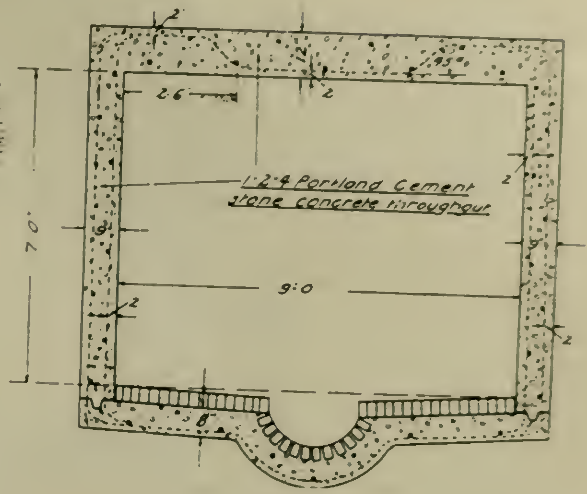
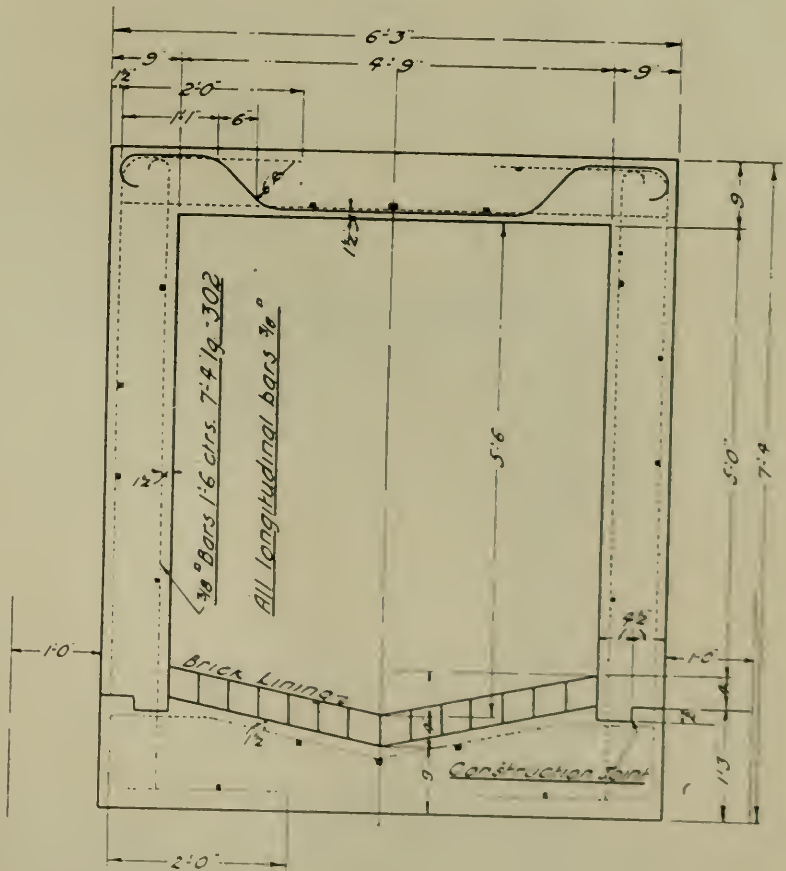


FIG. 7.



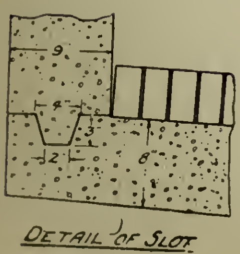


FIG. 8.

FIG. 9.

It will be seen from *Fig.* 6 that the invert is sloped towards a narrow channel 2 ft. wide; this is intended to take the minimum dry-weather flow. In *Fig.* 7 this is lined with bricks.

D

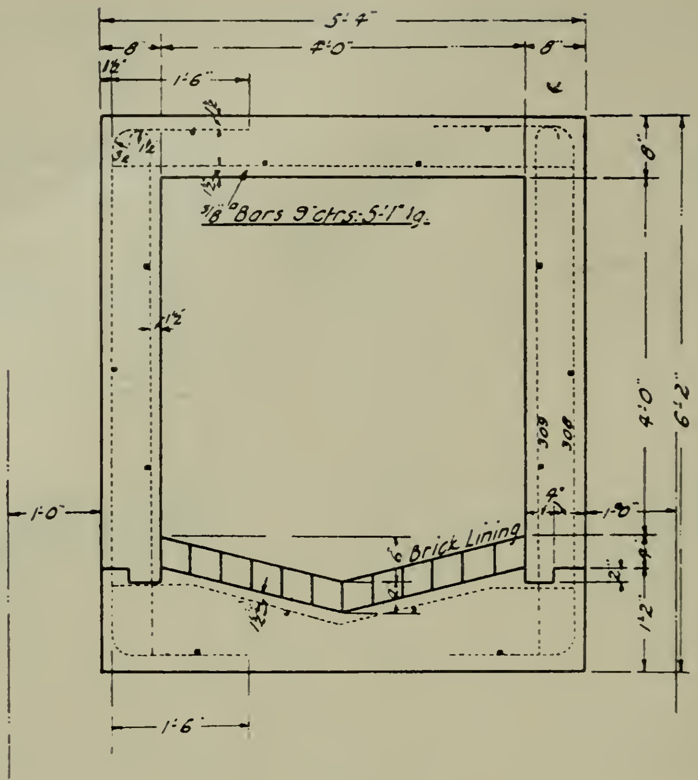

5'4"
8
4'0"
8"
1½"
1'6"
⅜" Bars 9" ctrs. 5'1" lg.
1'0"
Brick Lining
8"
4'0"
6'2"
1'2"
1'0"
1'6"

Fig. 10.

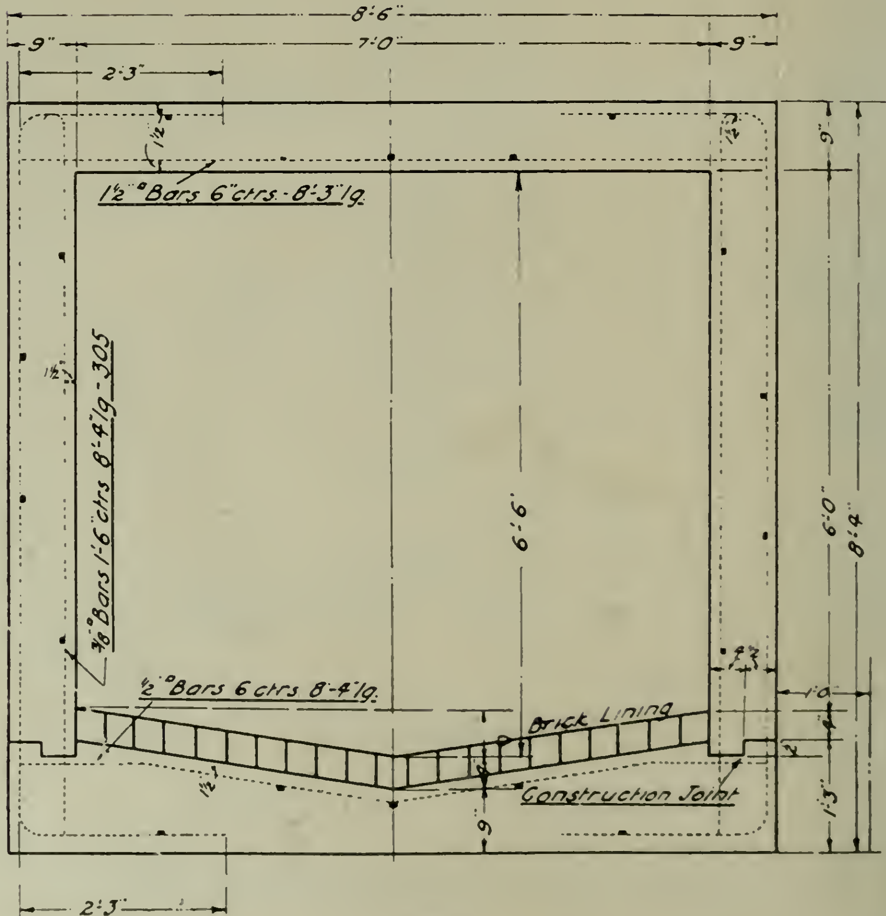

8'6"
9"
7'0"
9"
2'3"
1½" Bars 6" ctrs. 8'3" lg.
⅜" Bars 1'6" ctrs 8'4" lg - 305
½" Bars 6 ctrs 8'4" lg.
Brick Lining
Construction Joint
6'6"
9"
6'0"
8'4"
1'0"
1'3"
2'3"

Fig. 11.

The base slab is 12 in. in thickness, and formed of a 1 : 2½ : 5 mixture of Portland cement concrete ; it is not reinforced. The walls are 12 in. thick, and reinforced with vertical and horizontal reinforcement.

The structure (*Fig.* 6) is 10 ft. 6 in. wide (inside measurement), and 6 ft. 6 in. high.

The roof varies in thickness from 12-in. in centre to 9-in. at the supports, and is reinforced by ¾-in. square steel bars and shear members. The lower portion of the culvert is rendered with 1 in. of 1 to 2 Portland cement mortar. Where the walls meet the base slab they are " keyed " in as shown.

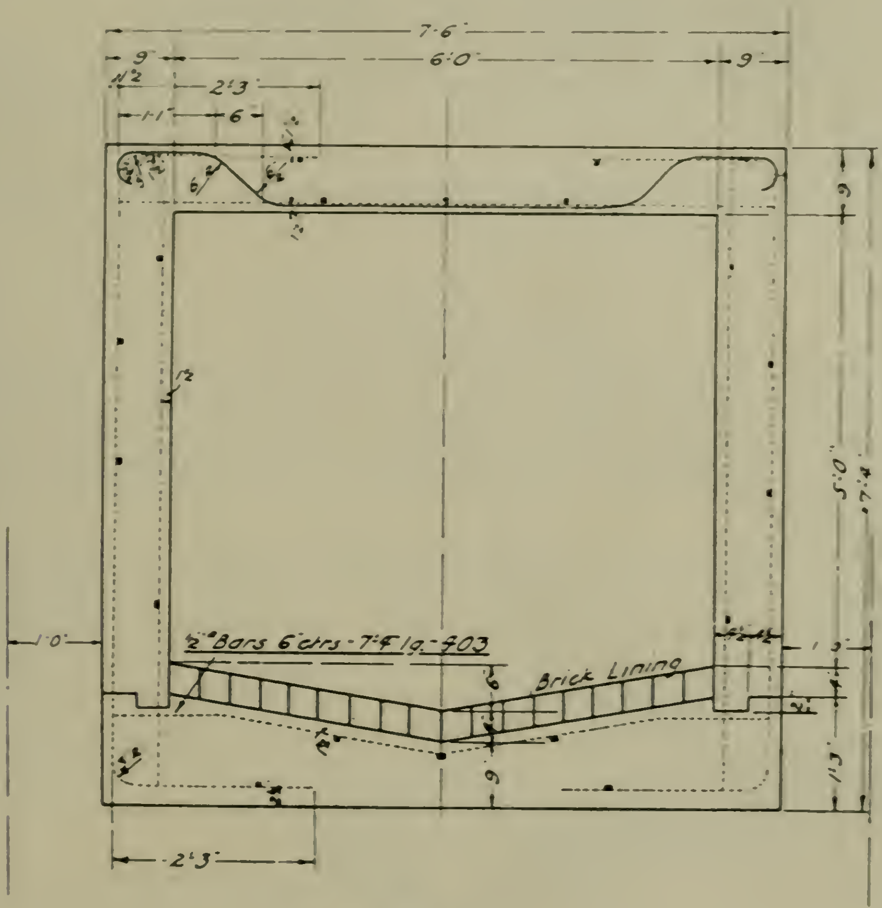


Fig. 12.

The reinforcement of the walls consists of ⅜-in. square steel bars at 18 in. and 12 in. centres, and ⅝-in. steel bars carried well down into the base slab. The minimum covering of the reinforcement is 1½ in.

This section of sewer has been constructed from Primrose Avenue to East 114th Street.

Two 12-in. sanitary pipe sewers encased in concrete have been laid adjoining this culvert.

A reinforced concrete sewer 7 ft. × 9 ft. rectangular section is shown in *Fig.* 7. The floor of this structure is 8 in. in thickness, and reinforced by the insertion on the lower side of the slab of ⅝ in. square twisted bars at 6 in. centres, with a 2-in. covering of concrete.

The whole of the invert is lined with vitrified bricks, and the concentrated invert is 2 ft. wide, and is also brick-lined.

The walls are 9 in. in thickness and are reinforced by two rows of $\frac{1}{2}$-in. vertical bars, twisted, at 6-in. centres, and horizontal bars.

A detail of the "slot" is shown in *Fig.* 8.

The roof slab is 12 in. thick and shear members are inserted. The main reinforcement in the roof slab is $\frac{3}{4}$ in. twisted bars at 4 in. centres.

A 1 : 2 : 4 Portland cement mixture was used throughout.

Smaller sections are illustrated in *Figs.* 9 and 10.

Fig. 9 illustrates a sewer 5 ft. 6 in. in height, and 4 ft. 9 in. in width. The invert falls uniformly towards the centre, and is brick-lined.

The walls are 9 in. in thickness, the roof slab 9 in., and the base slab from 9 in. to 15 in. The walls are reinforced by $\frac{3}{8}$-in. bars (vertical) spaced at 1 ft. and 1 ft. 6 in. centres, and horizontal bars. The roof slab reinforcement consists of $\frac{3}{8}$-in. bars.

Figs. 10, 11 and 12 represent reinforced concrete sewers of similar design constructed in the City of Cleveland.

NEW BEDFORD, MASS.

Reinforced concrete sewers have been constructed in this city, not only where the ground has been firm and good, but where it has consisted of quicksand, and the City Engineer, Mr. G. H. Nye, informs the author that the results have been quite satisfactory ; the comparison too in cost with brick sewers has been satisfactory.

A brief description of some of these reinforced concrete sewers is as follows :

Reinforced Concrete Intercepting Sewer, Cove Street to Rivet Street.—This sewer is 7 ft. in height and 7 ft. 8 in. wide ; the walls are 12 in. in thickness, and the crown of arch 9 in. The walls are "keyed" into the foundation slab. The trench to accommodate this large sewer is entirely into rock, and before constructing this sewer a 15-in. sanitary pipe sewer was laid with two 6-in. pipes connected to it.

The reinforcement (plain round bars) was arranged as shown in *Fig.* 13, and all steel bars had a covering of $1\frac{1}{2}$ in. of concrete.

Typical Sections.—(*a*) *Fig.* 14 represents a typical section on a 6 ft. 6 in. × 7 ft. reinforced concrete sewer. The invert was formed in 1 : 2 : 4, the arch in 1 : $2\frac{1}{2}$: 5. The reinforcement consisted of $\frac{1}{2}$-in. round rods spaced at 6-in. centres, and $\frac{1}{2}$-in. square twisted rods at 12 in. centres. The invert slab is 9 in. in thickness, the sides 11 in., and the roof slab 9 in. The reinforcement was arranged as shown in *Fig.* 14 and a subsoil drain (10 in.) was laid under the centre of the invert.

(*b*) This is illustrated in *Fig.* 15 and is a similar sewer to (*a*). The method of putting in the forms is shown. A 12-in. sanitary pipe drain is laid under the sewer with two 6-in. drains leading to it.

The invert of the large sewer is not brick-lined.

(*c*) This represents a sewer of very different shape, and is suitable where the structure must be kept shallow. It has a flat roof, vertical sides, and slab invert, curved. A subsoil drain is laid under it. The floor varies from 9 to 12 in. in thickness, the walls are 10 in. thick, and the roof 7 in.

The arrangement of the reinforcement is as shown in *Fig.* 16. The inside measurements are :—Width 6 ft. 7 in., height 3 ft. 2 in. The roof slab is reinforced by the insertion of 6 in. steel joists where the cover is 8 in. or under.

(*d*) This sewer is of an unusual type (see *Fig.* 17) ; it is useful however where two sewers have to be constructed one over the other. In this particular case an 18-in. pipe sewer was first laid, and above this a reinforced concrete culvert 64 in. × 46 in. was constructed ; the walls are 9 in. in thickness, the

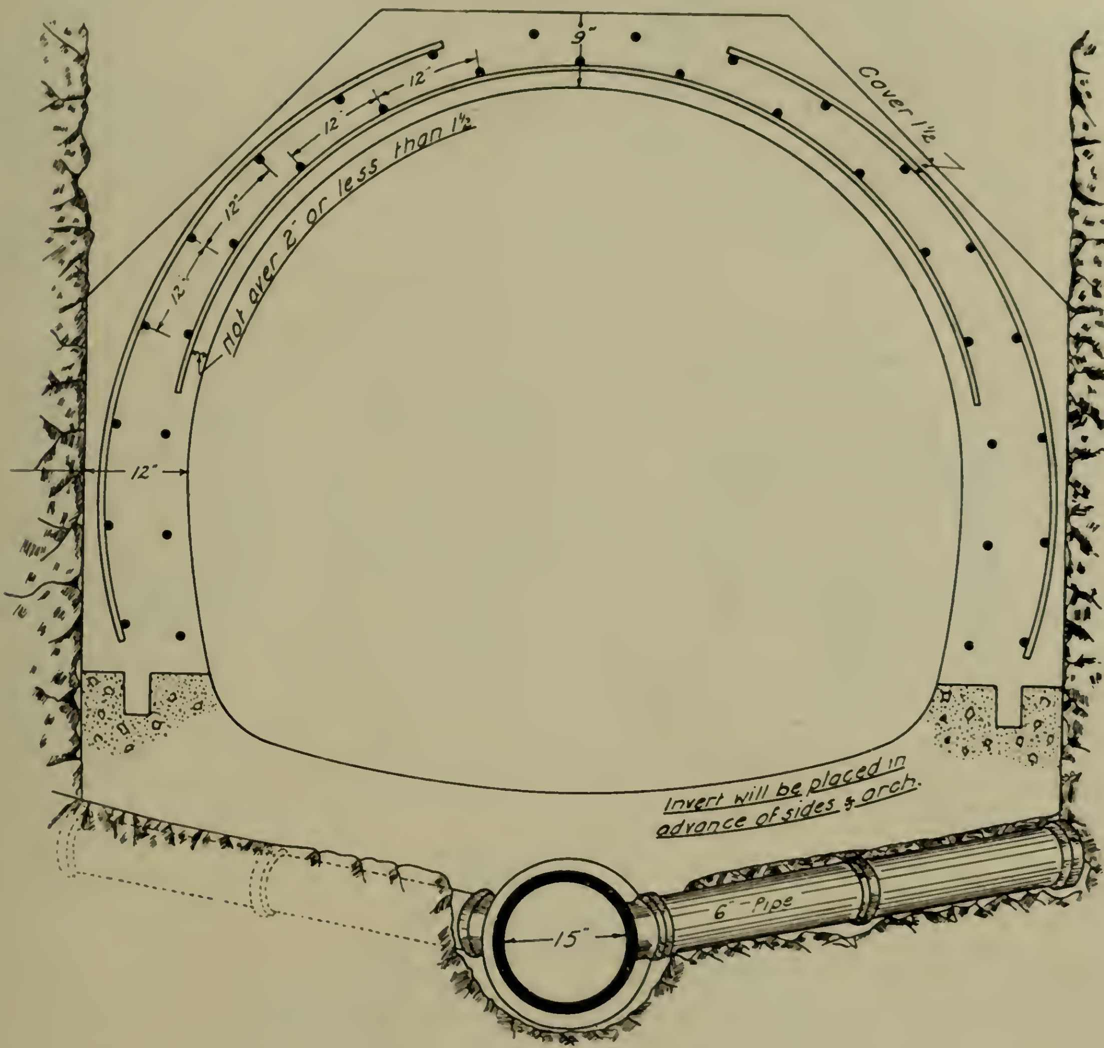


FIG. 13.

crown of arch 8 in., and the invert slab 14 in. The reinforcement consisted of ½-in. bars, and the sewer was built up of "*segments*."

(*e*) (see *Fig.* 18).—This is a simple form of construction and is a type of sewer much used in America. Sewers of this type are built up in segments, and the author recommends their use on the grounds of economy and strength. The reinforcement should not consist of rods of less diameter than ½ in., and the concrete used should be 1 : 2 : 4, or preferably 1 : 1½ : 3, for the invert, and 1 : 2 : 4 above this. The reinforcement should have a covering of at least 1½ in., and it will generally be found advisable, if the ground is waterlogged, to lay a subsoil drain under the culvert as shown in *Fig.* 18. The thickness of the invert slab in this particular sewer is 9 in., the sides 9 in., and the crown of arch 8 in.

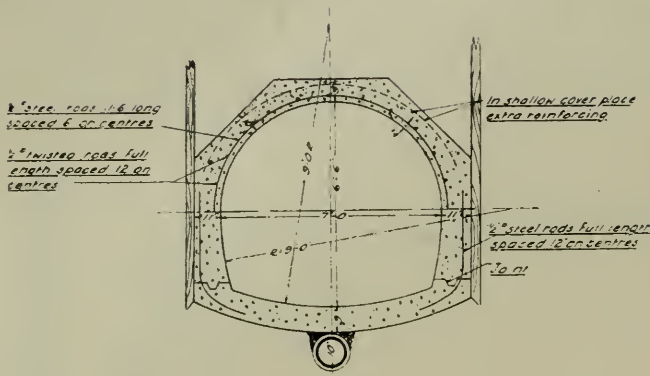


FIG. 14.

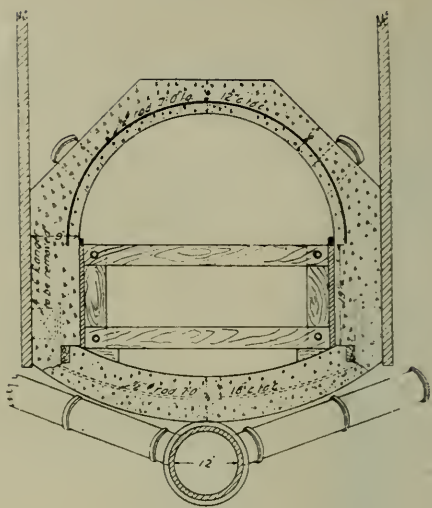


FIG. 15.

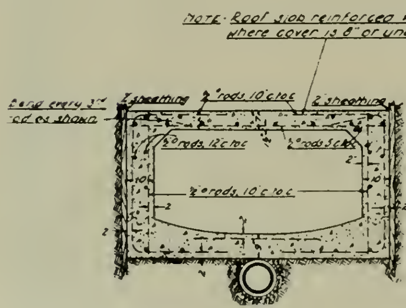


FIG. 16.

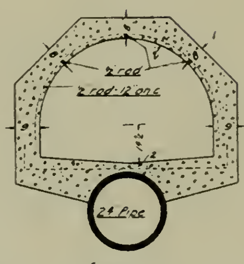


FIG. 17.

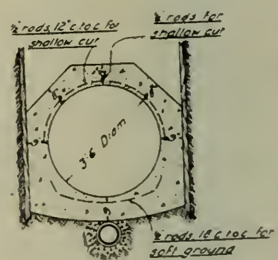
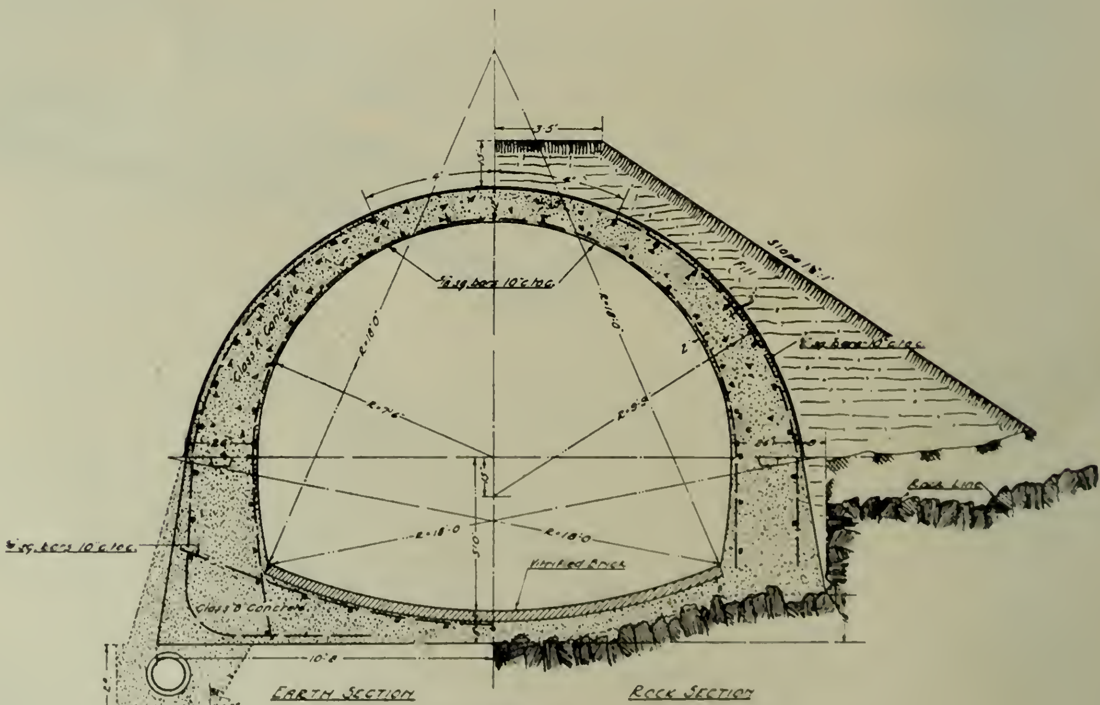


FIG. 18.



15' x 12'6" DRAIN

FIG. 19.

CITY OF BALTIMORE.

The Department of Public Improvements, of which Mr. A. E. Christhilf is the Highways Engineer, have constructed a number of large reinforced concrete sewers during recent years. These are of various forms and shapes, and it is the practice to line the invert of storm-water drains with vitrified bricks for 120 degrees, or one-third of the circumference.

In that city, as in many others, it is the custom to use pipe sewers for sewers up to 24 in. diameter, and for those above that size (including interceptors and outfall) to be constructed of either plain or reinforced concrete with brick-lined invert reaching to springing line. Where monolith concrete sections are not suitable, or a reinforced concrete section is more economical, the latter is used.

Reinforced concrete has also been used in the city's drainage system, but only where the velocities are 16 ft. or less per second, and for drains ranging from 30 to 54 in. in diameter, in which reinforced concrete pipe is usually much less costly than other materials.

The City Engineer informs the author that reinforced concrete sewers in Baltimore can be constructed cheaper than brick or masonry sewers.

There are many old sewers in that city that are of brick, and these are serving their purpose well, but sewers of a similar size to-day would cost less if in reinforced concrete.

Sewers of this type (reinforced concrete sewers) can be constructed quite easily in water-logged ground, and can be made perfectly watertight.

A brief description will now be given of one of the large reinforced concrete drains in Baltimore. This is the covering over " Jones Fall " through the city.

Gwynn's Run Trunk Drain—(Storm Water Contract), No. 42.—This was a huge undertaking. *Fig.* 19 represents the drain on a rock and earth section respectively. The size of this drain is 15 ft. × 12 ft. 6 in. The thickness of the walls on a line with the springing is 26 in., at base 35 in., and at the crown 12 in. The thickness of the invert is 8 in. (concrete), and it is lined with vitrified bricks to a depth of 4 in.

The foundations are into solid rock for a part of its length, and on earth for the remainder.

The double reinforcement (front and back) was arranged as shown in the sections, and it consisted of longitudinal and transverse bars of various sizes.

Generally.—(*a*) Great care must be taken to see that the natural foundations are good, and that it will bear the weight of the structure, together with the storm water that is passing through it during a storm.

(*b*) Use a fairly wet mixture in work of this class.

(*c*) Use a reliable aggregate, such as broken granite, suitable gravel, clean shingle, and clean, sharp sand.

(*d*) Use a 1 : 2 : 4 mixture of Portland cement concrete, and for invert (if not brick-lined) a 1 : 1½ : 3 mixture.

(*e*) All aggregate to be capable of passing through a 1 in. ring.

(*f*) Use only the best Portland cement.

(*g*) The invert should always be brick-lined.

EARLY ARMENIAN ARCHITECTURE.

The acquaintance of the English student with early Armenian architecture is, for the most part, slight, so that the opportunity recently afforded by the exhibition at the Victoria and Albert Museum must have been particularly welcome. The exhibition, which had already visited Paris, comprised a collection of drawings of architectural details and ornament by M. A. Fetvadjian of buildings and monuments dating from the sixth to the thirteenth century. These works, which are indeed some of the earliest expressions of the south and eastward spread Christian architecture, were scarcely known to Western students until the publication, in 1918, of Professor Strzygowski's two volumes, *Die Baukunst der Armenier und Europa*. This collection of drawings fully justifies the opinion gained from this book that these early works exhibit great skill and beauty.

The neighbourhood of Ani provides material for most of the architectural work. This town, which was the erstwhile capital of Armenia, possesses a fine eleventh-century cruciform cathedral, whose crossing was once crowned by a cupola. An ingenuity of cruciform planning is one of the characteristics of this early architecture, and apsidal ends, niches, conical roofings, provide a kind of geometric motif, in the treatment of which, with their various intersections of curved and plane surfaces, great skill is shown, and a peculiar beauty is evolved. Although the Armenians at the outset of their civilisation, we are told, were chiefly influenced by the architectural work of the Syrians and Coptics, by Byzantine traditions, and later by the arts of Georgia and Russia, these drawings seem to show clearly the seed that was later to develop into the ripe and splendid fruit of Gothic. In the ornament is displayed a freedom and invention that is most refreshing and inspiring, and if, by the study of it, architects might be persuaded to break loose from the shackles of the classic stock-in-trade of egg and tongue and the like, the exhibition will have achieved a fine result. We, who are concerned with the development of a new material or with the resuscitation of an old one, may learn much from this ornamentation, built up joyfully and sincerely from natural objects, and truthfully adapted to the material. It would almost seem to-day that nature has ceased to afford inspiration to the designer.

Concrete of a very fine quality played an important part in the construction of these early Armenian buildings. "The Churches," says Professor Lethaby in an illuminating introduction to the official catalogue, "were generally constructed of very finely jointed masonry in large blocks used as facings on both sides of the walls, and having a core of concrete. In later works the facings decreased in thickness and the main body of the work was of concrete." The adherence between the facings and the concrete is said to be extremely thorough so that even now the stonework is with difficulty detached. It is this resistance to disintegration that has led to the legend that the white of eggs was used in the concrete, which was actually composed of lime and large grained river sand well washed. To lighten the vaults pottery vessels were sometimes set in the concrete, and to this device the excellent acoustic properties are by some attributed. The method of construction described above is clearly indicated on certain of the drawings, which are executed with patience and lucidity, revealing prolonged study and accurate observation. The whole collection constitutes an unique record of these architectural monuments for the preservation of which, in graphic form, every art lover will be grateful. For they constitute another manifestation of the universal qualities which underlie all great art and particularly all great architecture. "They show," says Professor Lethaby, "once more how noble and reasonable forms of building vary from country to country, according to the materials obtainable, and the aspirations of different peoples ; but ever remains one Architecture—a long word which may be understood to mean reasonable building informed by the spirit of communities."

In addition to the water-colour drawings of the ruined buildings in and around Ani and to the drawings of architectural ornament, Mr. Fetvadjian shows, in water-colours, a series of sketches of Armenian women from various localities in their native costumes, with the various fabrics and adornments indigenous to each neighbourhood accurately and carefully portrayed. The thoroughness of the whole collection may to some extent be estimated by the fact that it represents work spread over some twenty years, and is not therefore the hasty impressions of a casual observer.

MEMORANDA.

Restoring Jedburgh Abbey.—In a lecture delivered in February to the Society for the Protection of Ancient Buildings, Sir Frank Baines gave an interesting account, illustrated by slides, of the restoration work in connection with Jedburgh Abbey. The piers supporting the tower were completely fractured and presented a very difficult problem constructionally. The solution finally adopted was to build a new concrete core to the piers, and steel needles supported on "shores" were used to carry the tower while this work was in progress. The slides showed the men at work in the "cuts," which were made in the piers working from the bottom upwards in stages of 3 ft. to 4 ft., and the method of inserting new concrete foundations reinforced with steel rods in place of the loose boulder-stones which were all that the original builders provided in the way of foundations.

Building in Chacabuco Street, Valparaiso.—The building shown on p. 260 is situated in the "Calle" Chacabuco, between the Avenida Francia and San Ignacio Street, Valparaiso, in the centre of the zone of the most complete destruction caused by the terrible seismic catastrophe of the 16th August, 1906, and is the property of the local co-operative annuity society, "La Co-Operativa Vitalicia." It was designed and constructed by Mr. Arthur Sthandier, a Belgian architect, many years resident in Valparaiso.

The general scheme, of which the present edifice is the commencement, provides for a public "Pasaje" through to the next parallel street, the Avenida Pedro Montt. The building up to the present, shown in the photograph, consists of six complete three-storeyed residences facing "Calle" Chacabuco, and two wings of two storeys high also containing six residences facing each side of the "Pasaje," totalling twelve modern dwelling-houses of six to ten rooms each, without counting service rooms or minor offices and conveniences.

The land in this quarter was originally reclaimed from the sea or foreshore, so the subsoil is composed of sand and marine refuse to a comparatively unlimited depth. There is no doubt that the universal destruction in this quarter by the earthquake was due in a very great measure to this circumstance, as there were proofs everywhere of *good* buildings suffering *comparatively* small damage where connected with its foundations, by cement, with the natural rock. Brickwork got cracked and badly broken up in upper storeys where the vibration was strongest, but the buildings did not fall. In view of the impracticability of reaching rock, even by piling, the architect found it necessary to adopt the raft system of foundation, by laying a perfect distribution of reinforced concrete beams, and slabs reinforced with B.R.C. fabric carrying the real foundations of the walls.

The exterior and party walls were constructed of steel framing with concrete filling. The floors, well-holes and stairs, minor partition wall, etc., also being of concrete reinforced as above.

Where wood-framed buildings and brickwork once held sway, now reinforced concrete has come to stay.

THE SMALL CONCRETE HOUSE IN AMERICA.

LATELY we have devoted our attention almost exclusively to the larger type of concrete house. This month, however, we reproduce from our American contemporary, *Concrete,* several illustrations of smaller houses, which set before us an example of good design and finish that is well worthy of emulation. As we point out elsewhere in our columns this month, sufficient time and money have been spent in the development of new systems ; what is now required is a better exploitation of the available methods, and the employment of better taste and finish in every concrete house. Many users of concrete are content to be able to show a cost figure slightly below that for similar accommodation provided by a competing material, notwithstanding the fact that in many of these cases the

FIG. 1. A STUCCO FINISHED CONCRETE HOUSE.

appearance of the house with its drab colour, its harsh textured surface, its box-like monotony of outline utterly devoid of any *finesse* or artistry is a thing of horror to behold. Successful exploitation of concrete will never come with such self-complacency, and the finger of contempt and ridicule will be pointed at the concrete house so long as this mistaken policy is pursued. And after all artistry need not necessarily be costly.

Fig. 1 is an illustration of a medium-sized house. It will readily be admitted that this is, in appearance, superior to most of the English concrete houses of similar size. Despite its utter simplicity it has distinction and style, two essential qualities that are so often lacking in our own work. The little irregularities not consciously sought, but the outcome of the design, at once counteract any suggestion of mass production or machine manufacture. The walls are built of blocks finished with a rough floated stucco surface. The roof is covered with vari-coloured cement asbestos shingles. The proportion and the method of setting the windows and their shutters, the timber corbels at the eaves and the

FIG. 2. A CONCRETE HOUSE IN CALIFORNIA.

FIG. 3. A HOUSE AT PELHAM, NEW YORK, SHOWING SURFACE TREATMENT.

lintels, the thin verge line, these are the simple elements that synthesise into a design of great attraction.

Fig. 2 is the entrance to a small concrete house. This artificial stone work is the only embellishment to the house, which otherwise relies on good surface, good details and finish for its effect. It is perhaps in the matter of surface treatment that our English work leaves most to be desired. For the most part an

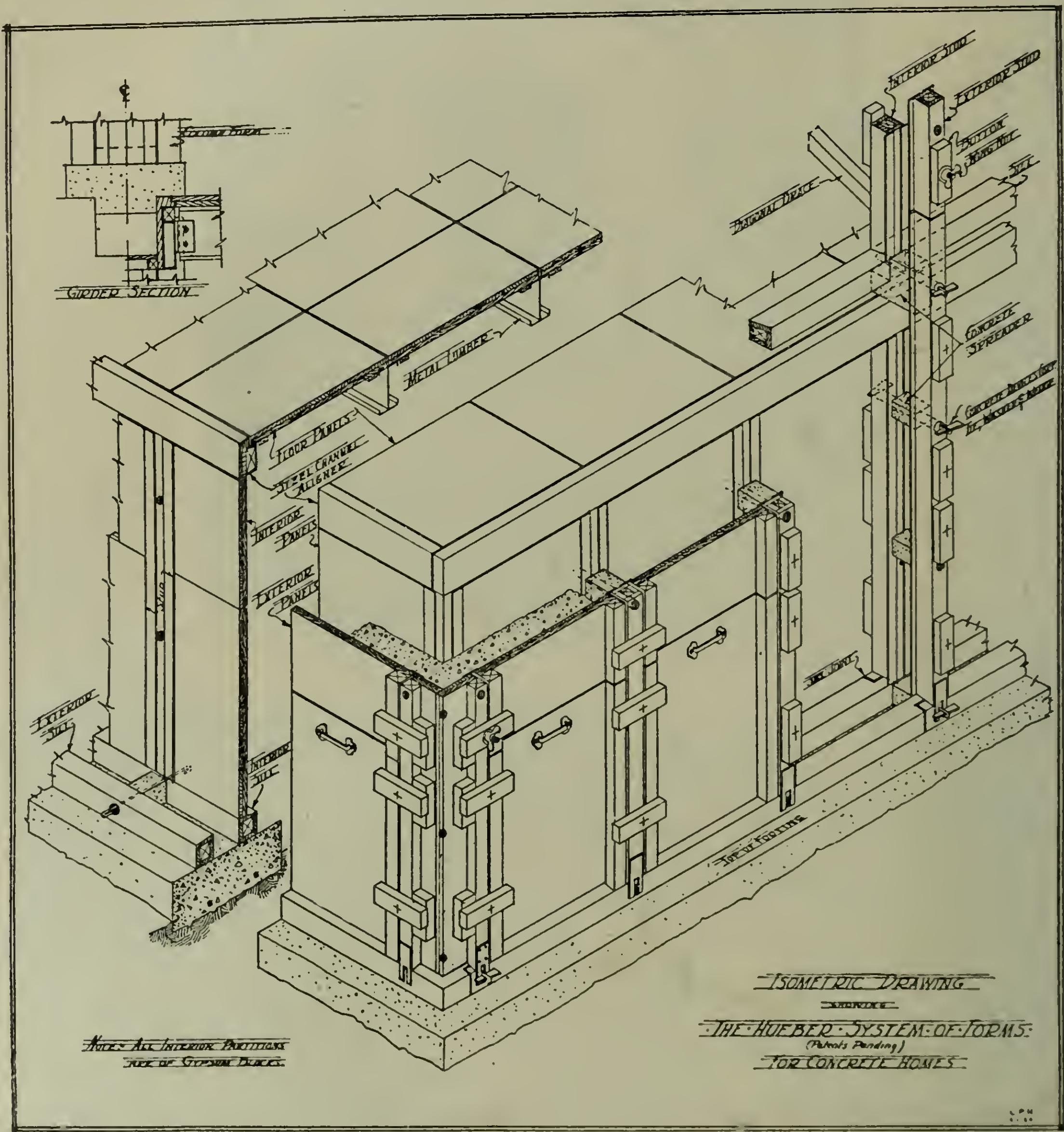


FIG. 4. ISOMETRIC PROJECTION OF HUEBER SYSTEM.

unprepossessing greyness alternates with the ubiquitous rough cast. Here in *Fig.* 3, however, we have an example of what can be done by the intelligent use of a finish of cement rendering. The photographs are self-explanatory. The lines, which give such interest to the wall surface, are the natural sweep of the trowel ; an indication of manual labour of which there is no reason to be ashamed. In the same way brush marks or even finger prints may be made not only the legitimate means of decoration, but a decoration of the highest artistic quality since it is one that emerges from the proper use by the craftsman of his material.

Considerable ingenuity has been expended in America in the development of " forms." *Fig.* 4 shows an isometric projection of the Hueber system. Light timber studs are attached to the cills which rest on the foundations. Two-ply panels are held in position between these studs by means of wooden buttons

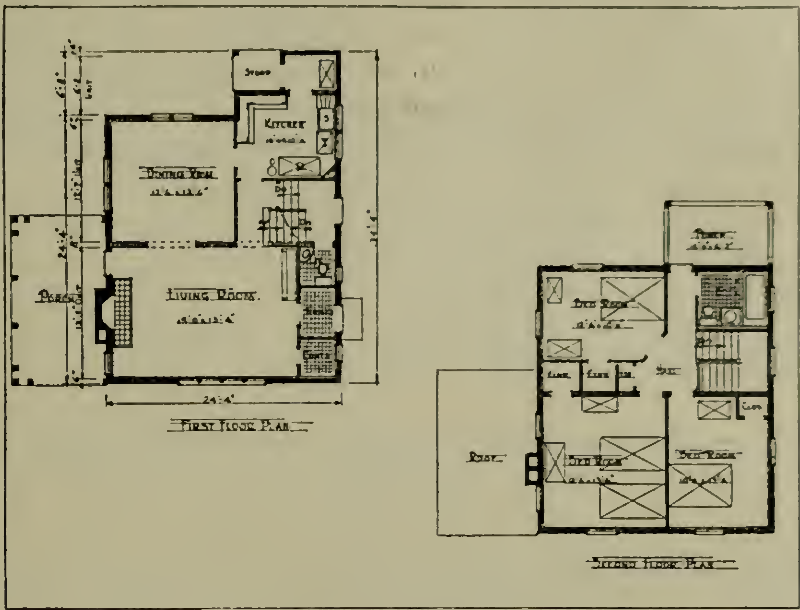


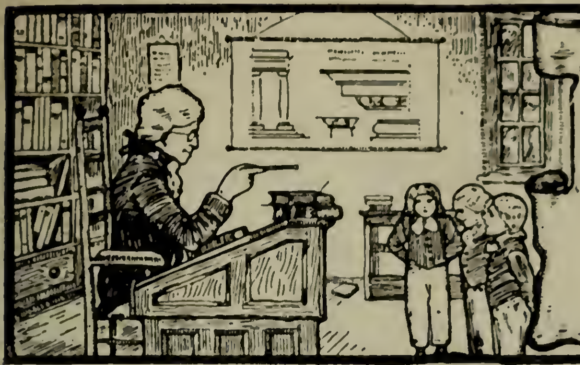
FIG. 5. PLANS OF A HUEBER HOUSE.

FIG. 6. INTERIOR VIEWS OF A HUEBER HOUSE.

tightened by wing nuts. Between the inner and outer forms are placed pre-cast concrete space blocks pierced for rods which are held temporarily in place by means of keys. The floor panels are supported on R.S.Js. Particulars of the time and labour required for the erection of a small house measuring on plan 25 ft. by 31 ft. may be of interest. The labour employed comprised one carpenter and five labourers. The erection of the forms was completed in four eight-hour days ; pouring, placing reinforcement and erecting scaffold, three days ; stripping and cleaning forms, two days. So that in nine days the concrete shell, comprising walls and floors, was complete. As is usual in America with this type of building, the cavity, which we place in the middle of the wall, is formed between the concrete and the plastering, the lathing being held away from the wall by means of firring. Experiments are now being carried out with cork board, which it is hoped to be able to apply direct to the concrete, thus obviating the necessity of a cavity, since it is thought that the cork board will in itself constitute a sufficient insulation, and a skimming coat can then be applied direct to the boards. Plans and interior views of a house built by means of this shuttering are shown in *Figs.* 5 and 6. The plan is compact and well conceived, and most of the rooms are large. The liberal cupboard space and large bathroom will particularly appeal to English house builders. The interior views show that cheapness has not been the only consideration. The houses are in good taste and the detail is simple and elegant. The reason for this may be partly due to the fact that the firm of Hueber Brothers includes an architect who is responsible for the designs. This is the satisfactory way to produce good results.

There are various other systems employed in America, most of which have their counterpart in this country, such as pre-cast units, expanded metal lathing and stucco, and, of course, the block in all its manifold forms. Many of these systems have their limitations and can only be made to operate economically where an extensive site is to be developed by the one method, and where labour can be organised and machinery and plant can be centralised. It is, however, from the use of the simpler methods that the ultimate extensive use of concrete is to be sought, and this will only come about as more beautiful results are obtained. This is the lesson that we have to learn from America. Our native traditions and standards of domestic architecture are still the highest in the world. It behoves us to remember this when we design in concrete.

Building in Chacabuco Street, Valparaiso. (*See page* 255.)



SIMPLE EXAMPLES OF REINFORCED CONCRETE DESIGN.

(Continued.)

By OSCAR FABER, O.B.E., D.Sc., etc.

(Continuation of same Example as February issue.)

INTERIOR MAIN BEAMS.—These carry concentrated loads at the third points, each load being the total load from a secondary beam (62,500 lb.).

If the beam were freely supported, the bending moment would be $B = \frac{Wl}{6}$ at the centre and nothing at the ends.

With continuous beams, it is desirable to make both ends and centre strong enough to resist two-thirds of this moment, i.e.,

$$B = \frac{Wl}{9}$$

that at the centre being of course positive and that at the ends negative.*

This gives

$$B = \frac{Wl}{9} = \frac{125{,}000 \text{ lb.} \times 300 \text{ in.}}{9} = 4{,}167{,}000 \text{ in. lb.}$$

Referring to the author's Standard T beams (*R.C.S.E.*, p. 35), this clearly requires a beam 30 in. × 12 in. over all with ten $1\frac{1}{4}$ in. bars.

As regards the strength of the compression boom (formed by the floor slab) the table indicates 66 in. wide and 9·9 in. deep as being required.

Our slab is only 5 in. thick, and the available width is limited to (see *R.C.S.E.*, p. 34)

(*a*) distance between beam	= 300 in.
(*b*) one quarter the span	= 75 in.
(*c*) twelve times slab thickness	= 60 in.

whichever is less.

Actually then, our slab is approximately the correct width, but only half the required depth.

This means it will carry about three-quarters the necessary compression, as an inspection of the stress diagram indicates that the upper half of the compression triangle has three-quarters the total area.

Compression steel must therefore be used to carry about one-quarter the total compression.

The total compression is

$$C = \frac{B}{a} = \frac{4{,}167{,}000}{24 \cdot 2} = 172{,}000 \text{ lb.}$$

The concrete slab (with an average stress of 450/lb. in.²) carries

$$C = 60 \text{ in.} \times 5 \text{ in.} \times 450 = 135{,}000$$

leaving the steel to take 37,000 lb.

The additional stress on each square inch of compression steel will be

$$c = 14 \times 450 = 6{,}300 \text{ lb./in.}^2$$

if it is centrally disposed in the slab, so that the area required is

$$A = \frac{37{,}000}{6{,}300} = 5 \cdot 9 \text{ in.}^2$$

* This is a rough approximation only. For exact values, see *Reinforced Concrete Design*, Vol. 2.

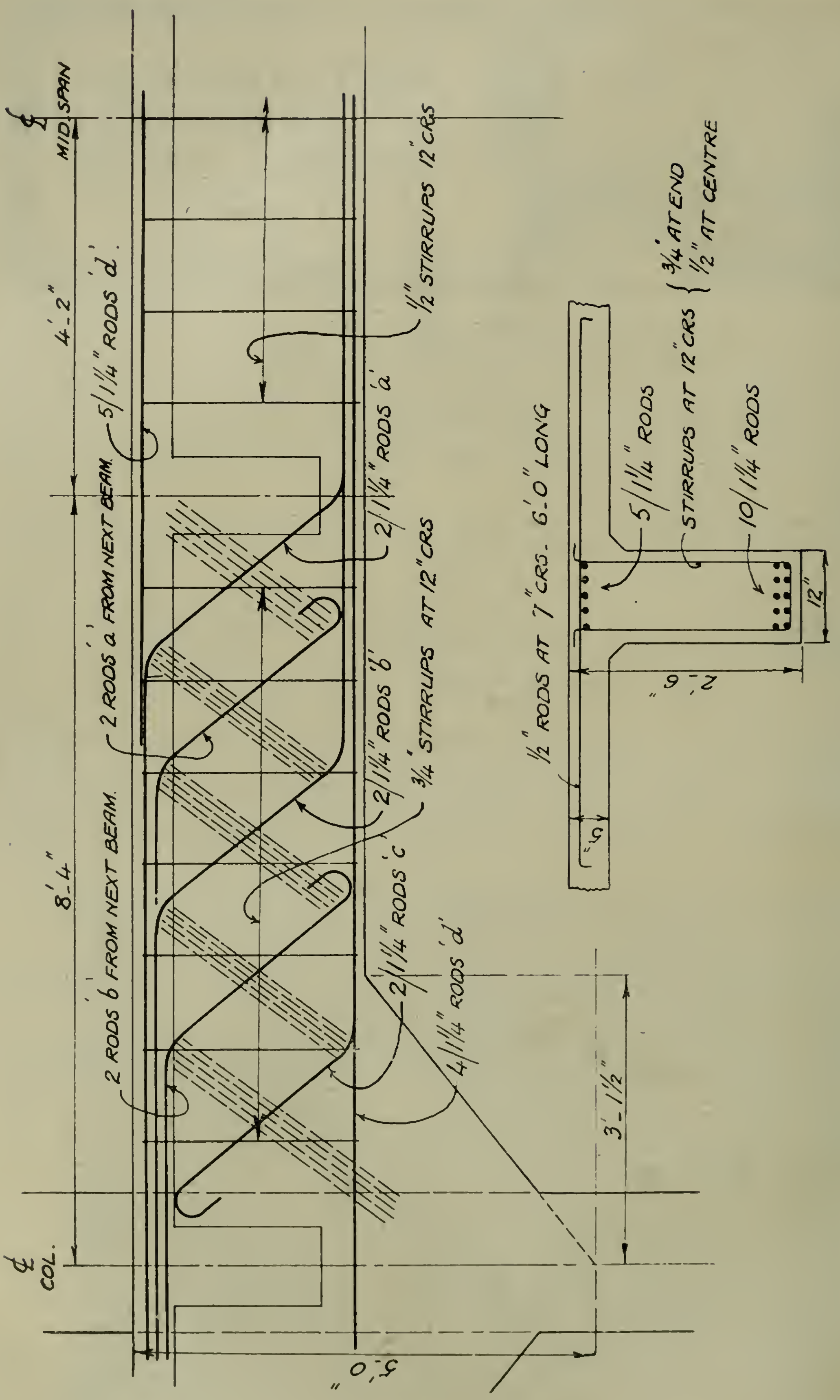


FIG. 10. DETAILS OF INTERIOR MAIN BEAM.

Five $1\frac{1}{4}$ in. rods give

$$5 \times 1\cdot22 = 6\cdot1 \text{ in.}^2$$

We must remember to insert in the slab, bars 60 in. long crossing the main beam, to tie the slab to it for the width we are using; $\frac{1}{2}$ in. rods at 7 in. centres will be suitable (as used for the main slab reinforcement). (See *R.C.S.E.*, par. 48, p. 34.)

Negative Moment at Support.—As already stated, we will take

$$B = -\frac{Wl}{9} = -4,167,000 \text{ in. lbs.}$$

Adopting the rule given in *R.C.S.E.* (p. 37) for the author's standard **T** beams we use a haunch to give an overall depth at the column of

$$N = 2 \times 30 = 60 \text{ in.}$$

and let thus die away at a distance of $\frac{l}{8} = 3$ ft. $- 1\frac{1}{2}$ in. from the centre line.

As a check on this, note this would give a resisting moment of

$$R = 95\ bd^2 = 95 \times 12 \times 57^2$$
$$= 3,700,000 \text{ in. lb.}$$

This is just under what is required, but the presence of more steel at the top than ·675 per cent. will make up the difference.

Actually provided ten $1\frac{1}{4}$ in. rods	$= 12\cdot2$ in.^{2}
·675 per cent. would be $\frac{\cdot675}{100} \times 12 \times 57$	$= 4\cdot6$,,

Shear.—The Shear, with this load distribution, is uniform from support to the nearest third point, and has a value equal to half the load on the beam, namely,

$$S = 62,500 \text{ lb.}$$

If the bars are bent as in *Fig.* 10, then the shear resisted by the bent-up bars is

$2 \times 1\cdot22 \times 10,000 \times \frac{24 \text{ in.}}{30 \text{ in.}}$	$= 19,600$ lb.
Inclined compression	$= 19,600$,,
$\frac{3}{4}$ in. stirrups at 12 in. centres	
$2 \times \cdot44 \times 10,000 \times \frac{24 \text{ in.}}{12 \text{ in.}}$	$= 17,600$,,
	56,800 lb.

Having regard to the conservative basis of design, this would be satisfactory.

The centre third has properly no shear when the load is uniform. But unequal loading can produce some, and a minimum reinforcement of $\frac{1}{2}$ in. stirrups at 12 in. centres is desirable.

MAIN BEAMS IN WALLS.—These differ from the others in carrying only about half the floor load, but also carry a wall.

Taking two-thirds the free moment, both at centre and support, the moment would be

from floor $\frac{Wl}{9} = \frac{62,500 \text{ lbs.} \times 300 \text{ in.}}{9}$	$= 2,080,000$ in. lb.
from wall $\frac{Wl}{12} = \frac{[25 \text{ ft.} \times 450] \times 300 \text{ in.}}{12}$	$= 280,000$ in. lb.
	2,360,000 in. lb.

This assumes the wall to consist of the concrete beam 3 ft. high, 12 in. thick, the weight of window being negligible, and giving a maximum of light.

Our beam is then 3 ft. 5 in. overall.

Treating this as a rectangular beam singly reinforced (because clearly at midspan the slab will not be available on the compression side) we have the resisting moment.

$$R = 95bd^2 = 95 \times 12 \times 38^2$$
$$= 1,650,000 \text{ in. lbs}$$

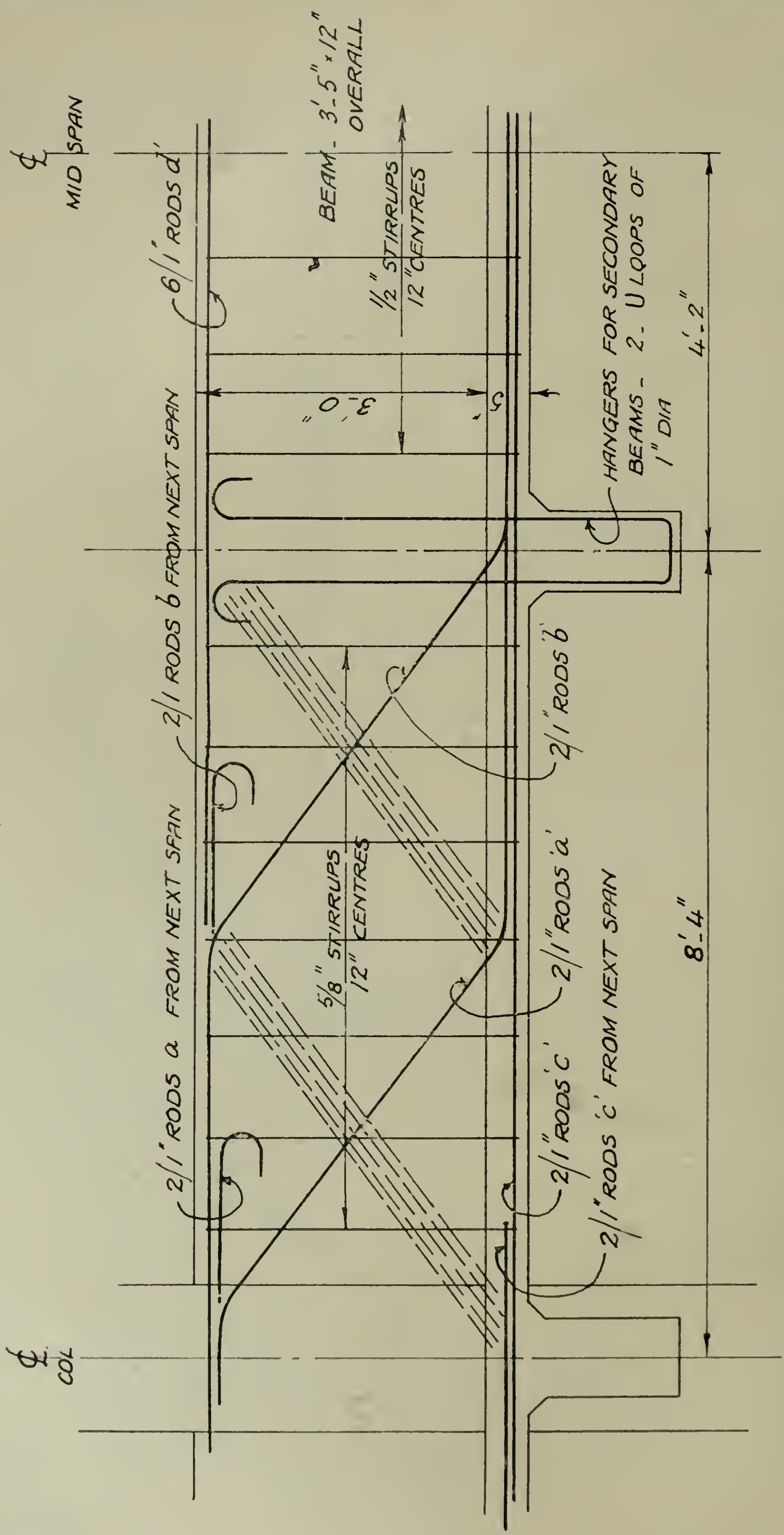


FIG. 11. DETAILS OF MAIN WALL BEAMS.

This being insufficient, the beam will need reinforcing on the compression side. We will therefore design it on the L.C.C. rule of using equal area of steel top and bottom, in which case the area of steel required is

$$A_s = \frac{2{,}360{,}000}{\cdot 88 \times 38 \times 16{,}000} = 4\cdot 45 \text{ in.}^2$$

Six 1 in. rods gives $6 \times \cdot 78 = 4\cdot 68$ in.^{2}

Reverse Moment of Support.—The moment being the same, and the beam being symmetrically reinforced, the centre section will apply equally well at the ends.

Here we also have a slab to help in compression, but it is all one side and therefore needs special consideration owing to its eccentricity.

Shear.—The total Shear is

From secondary beam	31,250 lb.
From wall ($12\frac{1}{2} \times 450$)	5,600 ,,
	36,850 lb.

Adopting the arrangement of *Fig.* 11 and designing as before, the shear resistance due to

Inclined rods $= 2 \times \cdot 78 \times 10{,}000 \times \frac{36 \text{ in.}}{58}$.	=	9,700 lb.
Inclined compression	=	9,700 ,,
Stirrups $\frac{3}{8}$ in. at 12 in. centres $2 \times \cdot 3 \times 10{,}000 \times \frac{36}{12}$	=	18,000 ,,
		37,400 lb.

A special point arises in this beam which is usually absent.

The load being applied at the bottom instead of at the top clearly increases the tension in the shear reinforcement, and care has to be taken in a beam of this kind to see that the bottom loads are well slung up.

In the case of the point loads from the secondary beams, this is best done by adding special hangers as shown, thus carrying the load up to its normal position at the top of the beam.

As the load from each secondary beam is 31,250 lb., four sections of 1 in. rod would give a stress of

$$\frac{31{,}250}{4 \times \cdot 78} = 10{,}000 \text{ lb/in.}^2$$

This is a safe and desirable stress in such a member.

(*To be continued.*)

MEMORANDUM.

Building Exhibition at Turin.—The first international building industries exhibition to be held in Italy, is the "Building Exhibition," at Turin, which opened on April 8 and continues until May 21, "saving prolongation," as the official translation of the notice says. Of the nine classes of exhibits, the first three are (1) *Building Materials*—lime, cement, bricks, natural stones, ceramics, metals used for building, asphalt, etc.; (2) *Machinery*, including tile, pipe and brick-making machines; (3) *Building Systems* and their application, viz., "concrete, blocks, ropes, special concretes, etc." As concrete, its chief constituent and the machinery for making it, are placed in the first three classes of exhibits, it may fairly be assumed that concrete will form a prominent feature of the first Italian Building Exhibition

AMERICAN STANDARD SPECIFICATION FOR CONCRETE.

A TENTATIVE Specification for Concrete and Reinforced Concrete has just been issued in America by a Committee having the same status in the United States as the Engineering Standards Committee in England. This Specification is designed to become a Standard Specification after such modification as may be necessary when the comments that are invited by the Committee have been considered. There are many who would welcome a British Standard Specification for concrete as tending to improvement in the quality, and it is indeed somewhat anomalous that for the production of a material of which the two most important ingredients, viz. cement and steel (when reinforcement is used), are the subject of stringent standard specifications, no such standard exists. It is proposed to call attention to certain features of the suggested American specification which are worthy of note.

Quality of Concrete.—The Specification has three alternatives for the engineer's choice, of which one requires that " the contractor shall use materials so proportioned and mixed as to produce concrete of the required workability and strength," and thus it merely devolves upon the engineer or architect to specify the required consistency and the required compressive strength at twenty-eight days.

This is a departure from the existing method of specifying the exact proportions of cement, fine and coarse aggregates, and it should tend to good workmanship and economy, because any reduction in the proportion of cement used will be a direct gain to the contractor, and such reduction can usually be obtained by greater attention to the grading of the aggregate and the mixing of the concrete. With the present system the contractor's only incentive to get the best out of his concrete is the necessity to safeguard his reputation for good work, but with the specification as now drafted, he can save money by bringing his mixing and grading to the highest pitch of excellence he can attain. On the other hand, the suggested procedure may have a serious aspect for the contractor because the tests upon which the concrete is judged do not mature until twenty-eight days after the concrete has been laid, when in many cases it would be under a considerable mass of superimposed work, so that condemnation of concrete on tests might prove very costly to the contractor.

Aggregates.—The Specification for fine aggregate is so comprehensive in its description as to be worth copying in full :—

" Fine aggregate shall consist of sand, stone screenings or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances."

For fine aggregate not more than 5 per cent. residue on a 4-mesh sieve is allowed, and not more than 30 per cent. may pass through a 50-mesh sieve; the amount of clay, loam and dust removable by decantation is limited to 3 per cent. A 3 to 1 mortar containing the fine aggregate is preferably to have the same tensile or compressive strength as when standard sand is used with the same cement and at the same consistency, but this requirement may be waived if the concrete (containing also the coarse aggregate) has the specified strength. The size of coarse aggregate is left to be inserted in the Specification by the engineer, except that not more than 15 per cent. is to pass a 4-mesh sieve, nor more than 5 per cent. is to pass an 8-mesh sieve.

Deformed Bars must develop a bond strength at least 25 per cent. greater than that of a plain round bar of equal cross-sectional area.

Consistency of Concrete.—The slump test * is to be the basis of consistency and the recommended figures are 1-in. slump for machine-finished roads, 2-in. slump for mass concrete, 6-in. slump for thin vertical reinforced sections, columns, etc.

Mixing is to be done in a batch mixer and is to continue not less than 1½ minutes with a rotation at a peripheral speed of about 200 ft. per minute. When hand mixing is authorised materials are to be turned at least six times after the water is added. Hand mixing is prohibited for concrete to be deposited under water.

Curing.—Exposed surfaces of concrete subject to premature drying are to be kept thoroughly wetted for at least seven days.

Cold Weather.—Concrete mixed and deposited during freezing weather must have a temperature between 50° and 100° F., and a minimum temperature of 50° F. must be maintained for at least seventy-two hours.

Reinforcement must be protected from moisture in footings by at least 3 in. of concrete and in fire-resistive construction 1 in. protection of reinforcement is required in slabs and walls and 2 in. in beams, girders and columns, but where aggregate having a greater tendency to expansion than limestone or trap rock is used, further protection of reinforcement from fire is required.

Waterproofing.—" Integral compounds shall not be used."

Sea Water Work.—Plain concrete in sea water is to contain not less than 6 cu. ft. of cement per cu. yard of concrete *in situ*, and not less than 7 cu. ft. cement per cu. yard of concrete at places between 2 ft. below low water and 2 ft. above high water. Slag, broken brick or porous or weak aggregates are excluded.

Surface Finish.—Any water coming to the surface of the concrete after laying is to be drained off or otherwise promptly removed, and the sprinkling of dry cement or cement and sand on the surface is prohibited. For wearing surfaces, the mix is not to be leaner than 1 part cement to 2½ parts aggregate and the surface is to be screeded even, and finished with a wood float. Over-trowelling is to be avoided. In two-course work, the wearing surface shall be placed within half an hour after the base course and is not to be less than 1 in. The surface is to be kept wet for at least ten days in the case of floors and twenty-one days in the case of roads or pavements.

* See this Journal, Vol. xvi. pp. 535 and 612 (1921).

Methods of Testing.—The main specification is supplemented by appendices giving standard methods of making and storing concrete test-pieces, of making sieve tests of aggregates, of testing for clay and silt in aggregates, of making compression tests, of testing for organic impurities in sands and of making the slump test for consistency, together with standard specifications for cement and reinforcement. The specification is also accompanied by a table to be used as a guide to show what mixtures of aggregates of various sizes are required to produce concrete of any specified compressive strength from 1,500 to 3,000 lb. per square inch at twenty-eight days. The remarkable feature of this table is the fact that more than twice as much cement is required to produce concrete of a certain strength when a wet mix is used as compared with a dry mix. As an example, when a compressive strength of 2,000 lb. per square inch is required with coarse aggregate $\frac{3}{8}$-in. to 1 in. and fine aggregate from $\frac{1}{4}$-in., to dust, a mix of 1 : 3·3 : 3·8 would suffice if the slump test were $\frac{1}{2}$ in. to 1 in., whereas a mix of 1 : 1·3 : 2·0 would be needed if the slump test were 8 in. to 10 in.

From the foregoing summary it will be seen that the specification is comprehensive and leaves very little to chance. As already indicated, it is no more than a tentative standard at the present time, but it may be agreed that from a theoretical standpoint, at least, there is little fault to be found with it. It is probable that many contractors in this country would hesitate to saddle themselves with the responsibility of producing concrete of a given strength, and no doubt it will be the practice here for many years to specify the exact proportions to be used in the concrete. Indications are already in evidence in America that the specification will not go unchallenged by contractors in this particular connection.

MEMORANDUM.

Cambridge Arterial Road, Edmonton, Silver Street Section.—This road is being laid for the Middlesex County Council, under the direction of the County Surveyor, Mr. A. Dryland, M.Inst.C.E., in conjunction with the Edmonton Urban District Council Engineer and Surveyor, Mr. C. Brown, M.Inst.C.E. It is a complete concrete road reinforced with B.R.C. No. 9 fabric. We hope to publish fuller details later.

CAMBRIDGE ARTERIAL ROAD.

CONCRETE TANKS IN INDUSTRY.

The advantages of concrete tanks for holding water have long been recognised, and are too well known to need recounting. The success of these tanks for this purpose has, during the last decade or so, led to investigation as to the suitability of concrete for structures to hold other liquids, and the result is rather astonishing.

Fuel Oil.—In our issues for January and February the subject of concrete tanks for fuel oil storage was dealt with, and our readers will remember that we gave a few examples selected from a large number of such tanks which have been constructed in the United States. But there are many other industries which, having previously experienced difficulties in the storage of various chemical liquids, have now solved the problem by the adoption of concrete.

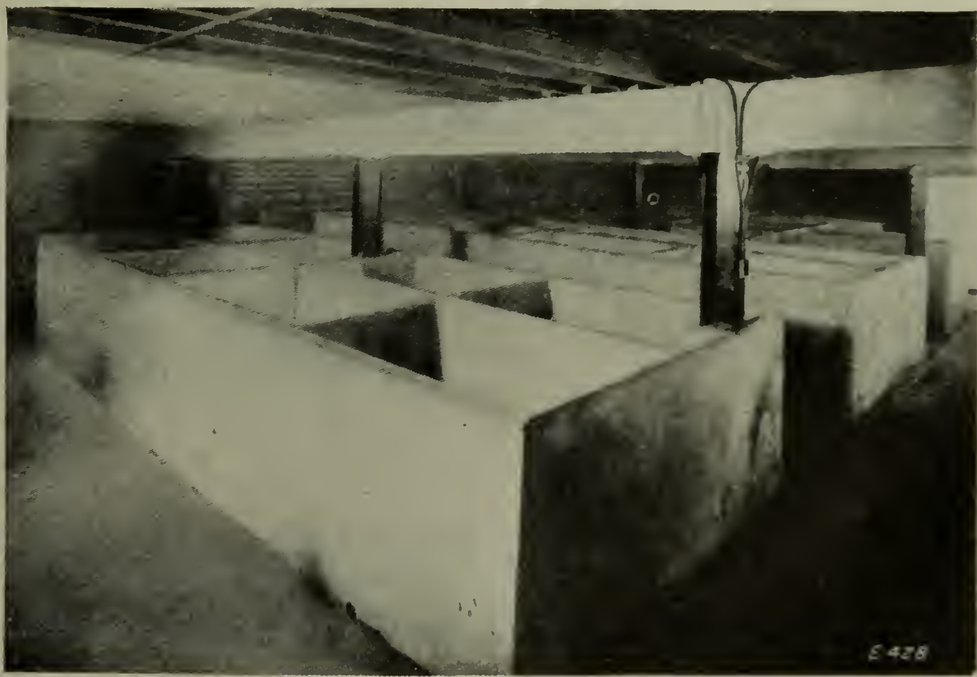


Fig. 1. Concrete Tanks containing Brine for Meat Pickling.

Vegetable Oils.—Besides mineral oil, there are other oils for which concrete is now successfully used as a container. One such is cottonseed oil, and we learn that four concrete tanks used for the storage of this oil were built in 1915, with a total capacity of 32,000 gals. These tanks were not surfaced in any way, and the Company report that they have had no trouble with any of them. In another case a tank is used to store not only cocoa-nut oil, but it is frequently used for the storage of glycerine.

Brine.—*Fig.* 1 shows a portion of ninety tanks, used for meat pickling. These tanks, built for a large New York firm in 1910, have a total capacity of 92,000 gals.; the report of the firm is worth quoting. "Have been in use every day and every hour since they were built. Have never leaked nor scaled, nor given the least trouble. . . . More satisfactory than old-fashioned vats in every way. There is no repair, they do not get greasy, there is no place for rats to hide, and there are no spaces for pieces of meat to drop into and be lost."

Another company has had fourteen tanks in continuous use since 1913. These were not given any special surface treatment, and the brine contained in

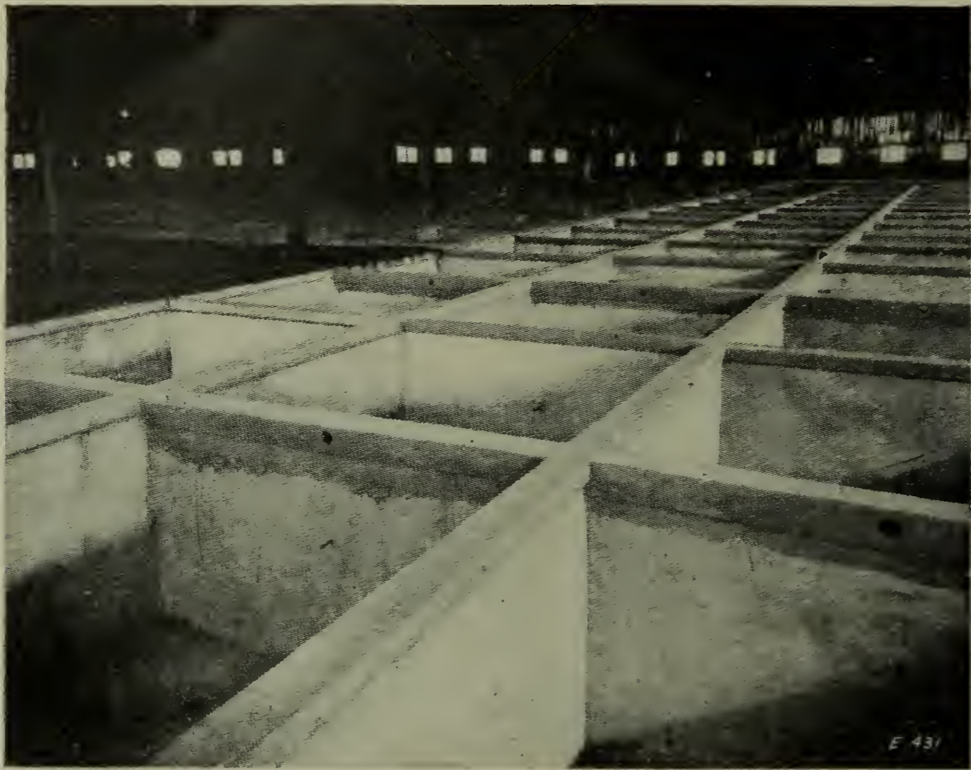


Fig. 2. Concrete Tanks for Tanning Liquors.

Fig. 3. Concrete Tanks for Log Boiling.

them is subjected to temperatures ranging from 100° to 160° F. The Company says, "They appear to get harder with salt contact and the heat."

Wood Pulp.—A company of paper board manufacturers had a number of concrete "stock chests" erected from 1908 to 1916 which have given every

Fig. 4. Concrete Gas Holder Tank.

Fig. 5. Concrete Tank for containing Sulphuric Acid.

satisfaction, while another firm has adopted concrete for bleach tanks which received no interior coating whatever.

TANNING LIQUORS.—*Fig.* 2 shows a battery of vats for tanning liquors. In one case such tanks have been in continuous use since 1905. No special treatment was adopted and there has been no noticeable effect either on the concrete or on the stored contents.

BOILING WATER.—Doubts are sometimes cast upon the ability of concrete to withstand the heat from boiling water. *Fig.* 3 illustrates a battery of seven tanks built in 1914. These are used for boiling logs before cutting them into veneer. The only interior surface treatment they received was a coating of 1 : 2 cement mortar.

GAS HOLDER TANK.—*Fig.* 4 shows a gas holder tank at Grand Haven, Michigan. This is a use for concrete which we can commend to the serious consideration of gas companies.

SULPHURIC ACID.—For the storage of sulphuric acid some kind of protection for the concrete appears to be necessary. The tank illustrated in *Fig.* 5 is one of two erected in 1910. In this case the lining is lead and the latest information available is to the effect that these tanks are in as good condition as when constructed.

MISCELLANEOUS.—Among the other industrial purposes for which concrete tanks are now being used are for the storage of molasses, buttermilk, calcium chloride, sodium silicate, zinc chloride, and ammoniacal liquors.

Needless to add, the secret of success in the construction of a tank for any purpose whatever, is correct design, suitable materials, and sound workmanship in its broadest sense; this includes proper proportioning, thorough mixing, immediate placing, effective protection during early hardening, and adequate curing.

For the illustrations and many of the examples quoted in this article we are indebted to the Portland Cement Association of U.S.A.

MEMORANDUM.

Concrete Construction in California.—*New Harbour Works at San Francisco.*—Concrete is being used in the construction of new harbour works at San Francisco, where the Board of State Harbour Commissions have recently placed a contract to construct the substructure, wharf and building foundations for the great China Basin terminal. This will consist of a reinforced concrete wharf 990 ft. in length, with 36 ft. of water alongside at low water. Facing the wharf will be a six-storey building, 812 ft. by 122 ft. on the first floor, and 812 ft. by 102 ft. on the five upper floors, giving a total floor space of 516,000 sq. ft.

The building on the upper floors will be set back, giving a 20-ft. platform on the second floor for receiving and handling cargo, from which, in addition to the wharf deck, it can be hoisted up to any floor above. In the back of the building a ramp will afford easy access to the second floor to all teams and motor trollies, at the same time keeping them away from the congestion of railroad lines behind the building. Along the ramp a " saw tooth " platform will extend the full length of the building, facilitating loading of trucks and economising space occupied by trucks on the ramp while loading or unloading.

One spur track on the wharf in front of the building and three spur tracks beneath the ramp behind the building, will give ample rail facilities, connecting by means of the State Belt Railroad with every railway reaching San Francisco Bay.

THE CONCRETE INSTITUTE.

MONTHLY NOTES.

By the SECRETARY.

THE CONCRETE INSTITUTE AT THE BUILDING EXHIBITION, 1922.

ALL members and many others interested have been advised by circular of the arrangements made for the holding of a series of Discussions on "Problems of the Moment," at the Building Exhibition, Olympia, in April, 1922.

The President and Council hope to see as many members as possible at these Meetings, and to meet them in the sitting-room reserved for members of the Institute, which will be situate over the main entrance, and will be furnished specially by Messrs. Waring & Gillow.

Attention is also drawn to the Fancy Dress Ball and Carnival arranged by the Architectural Association Schools in aid of their endowment fund, to be held on Friday, April 21. It is hoped that members will support this function, and tickets (£1 1*s*. single, and £1 15*s*. double, including refreshments) may be obtained from the Secretary of the Concrete Institute, 296, Vauxhall Bridge Road, S.W.1.

MEETING IN APRIL.

The Annual General Meeting of the Concrete Institute will be held at Denison House, 296, Vauxhall Bridge Road, S.W.1, on Thursday, April 27, 1922, at 7.30 p.m., when the Council's Annual Report for the year 1921–22 will be presented.

Following this meeting will be held the 111th ordinary general meeting, at which a paper (illustrated with lantern slides) will be read by Mr. E. F. Sargent, A.M.Inst.C.E., M.I.Mech.E., on "The Preparation of Concrete Aggregates" and "Moving Forms."

EXAMINATION IN MAY.

Examinations, Part I. for Graduateship and Part II. for Associate-Membership, will be held in London and at other centres as may be arranged, on Thursday and Friday, May 18 and 19.

A Syllabus and full particulars may be obtained on application to the Secretary of the Concrete Institute, 296, Vauxhall Bridge Road, S.W.1.

EMPLOYMENT REGISTER.

The attention of all members of the Institute who may require whole or part time assistance in their offices is drawn to the Employment Register of the Institute, which contains the names of many well-qualified candidates for such appointments. It is hoped that members will use this Register in preference to outside sources of labour supply.

CONCRETE AGGREGATES.—(*continued*).

Newbury (a).

(1) *General description :* Gravel.
(2) *Source and locality of same :* Gravel Pit, Newbury.
(3) *How obtained ?* Prepared by hand.
(4) *From whom obtained ?* Mr. G. Haddrell, Newbury.
(5) *Is available quantity limited ? If so, how ?* No.
(6) *Present maximum output per day (stated in cubic yards) :* 50 cubic yards.
(7) *Transport facilities :* By road or rail.
(8) *Is there any provision at or near source for washing or crushing ?* No.
(9) *Price per cubic yard, and where delivered :* 3*s.* 6*d.* at Pit.
(10) *Is composition uniform ?* Fairly.
(11) *Detailed description :—*
 (*a*) *Kind of stone or coarse material :* Flint.
 (*b*) *Kind of sand or fine material :* Siliceous.
 (*c*) *Relative proportions of coarse and fine material :* Vary (average 1 sand, 4 flints).
 (*d*) *Shape of particles (rounded, angular, flat, etc.) :* Angular, large and small.
 (*e*) *Size of particles ; approximate percentage, that needs crushing to pass* $\frac{3}{4}$ *in. screen :* 4 in. and downwards.
 (*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* Clay.
(12) *Is sample sent with this sheet ?* No.
(13) *General remarks :* Very commonly used. And they are making concrete blocks for building purposes at the present time.

Newbury (b).

(1) *General description :* Gravel.
(2) *Source and locality of same :* Newbury.
(3) *How obtained ?* Shallow pits—dug.
(4) *From whom obtained ?* Many owners.
(5) *Is available quantity limited ? If so, how ?* Unlimited supply.
(6) *Present maximum output per day (stated in cubic yards) :* Uncertain ; probably 200 cubic yards.
(7) *Transport facilities :* Motor lorries to railway station goods yard.
(8) *Is there any provision at or near source for washing or crushing ?* No—but plenty of water available.
(9) *Price per cubic yard, and where delivered :* 2*s.* 6*d.* to 3*s.* 6*d.* at Pit.
(10) *Is composition uniform ?* Yes.
(11) *Detailed description :—*
 (*a*) *Kind of stone or coarse material :* Flint gravel.
 (*b*) *Kind of sand or fine material :* Sharp sand.
 (*c*) *Relative proportions of coarse and fine material :* 3 of coarse to 1 of fine.
 (*d*) *Shape of particles (rounded, angular, flat, etc.) :* Rounded.
 (*e*) *Size of particles ; approximate percentage that needs crushing to pass* $\frac{3}{4}$ *in. screen :* 75 per cent.
 (*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* Negligible.
(12) *Is sample sent with this sheet ?* No.
(13) *General remarks :* If desired a large quantity (say 20,000 yards) could be put in canal boat at Thatcham from the Corporation Sewage farm.

CAPILLARY CANALS IN CONCRETE AND THE PERCOLATION OF WATER THROUGH THEM.

By E. B. MOULLIN, M.A.

Abstract from a Paper read before the Concrete Institute on Jan. 26, 1922.

ORIGIN AND SCOPE OF THIS PAPER.

The experiments which this paper attempts to describe were first suggested by reading the report on reinforced concrete issued by the Institution of Civil Engineers, which describes many experiments made in 1911 at the National Physical Laboratory on the percolation of water through concrete slabs.

The tests described in this paper were made over three years ago under very disadvantageous conditions in regard to available time and facilities for research. They are in a way a repetition of the National Physical Laboratory's experiments on a very small scale.

Attempts have also been made to examine the internal structure of hydrated cement and plaster by means of microscopic examination of thin sections.

A simple theory of the laws and conditions of absorption has been formulated, and its mathematical interpretation is found to be in very close agreement with experiments.

Description and Analysis of the Experiments made at the National Physical Laboratory in 1911.—These experiments showed the rather surprising fact that water does not pour through concrete at a constant rate. When the slab is first subjected to pressure, the water passes through fairly freely, but in the course of some thousand hours or so the rate of flow diminishes to about one-thirtieth part of the initial value.

Percolation and Absorption Experiments made by the Author.—The following experiments were all made on a very small scale.

Nature of Internal Structure as revealed by the Microscope.—Microscope slides were made consisting of thin sections of cement and plaster, thin enough to transmit light through them ; this is a method of attack familiar to petrologists.

Examination of cement in this manner clearly shows the remains of partly dissolved cement grains : in some cases the original internal crystalline structure of these grains is visible.

The intervening spaces between the grains are filled with a dense amorphous substance, which is presumably the result of the desiccation of the colloidal solution formed by the mixture of cement and water. Piercing through this amorphous substance are a large number of circular holes, which must be cross sections of spherical cavities in the block. In one slide there are fifty-five of these holes in an area of about 2 sq. cm. of cement.

The diameter of these holes varies from seven-tenths of a millimetre to a little under one-tenth of a millimetre, but as these holes are not necessarily diametral planes of the spherical cavities their diameter does not show the average size of the spherical hole. Probably ·7 mm. may be taken as an upper limit.

If a block of cement concrete is cut through and its surface ground dead flat, these cavities are easily seen, some being greater and some less than a hemisphere.

The insides of these cavities can be observed with the help of a powerful microscope, and viewed in this manner they present a remarkably beautiful appearance. The walls are completely covered with tiny crystals of varying hues of green, blue and grey, and in the absence of anything to give true scale to the picture they might be mistaken for a gem-studded grotto.

The depth of these cavities can be measured by noting the movement necessary to focus first on the top and then on the bottom of the holes. By measuring both the depth and the diameter of the cavity the volume of the sphere of which it formed a part is easily calculated. In the case of eight holes thus measured the radii of the spheres lay between one-tenth and five-tenths of a millimetre, giving volumes of $4{\cdot}2 \times 10^6$ cub. cm. respectively.

Thus the largest measured had 125 times the volume of the smallest, so there seems no tendency for the cavities to form equal in size. Exactly how these caverns are formed is not clear, but from their spherical shape they are presumably caused by drops of excess water. The slides taken seem to suggest that more cavities are formed close to a pebble of aggregate than not, but as they also appear in great abundance in plaster of Paris, the presence of pebbles is evidently not essential to the formation : neat cement blocks as a rule do not show many cavities.

No doubt these cavities are similar to those observed by Mr. N. C. Johnson, and referred to in Mr. Andrews' paper on " Some methods of securing impermeability in concrete."

Apparently the " Michaelis " theory of the setting of cement claims that there is a deposition of hydrated tricalcium aluminate from a supersaturated solution : and that this deposition takes place in a partly colloidal and partly crystalline form : an excess of water appearing to favour the formation of crystals.

In the slides shown the bulk of the cement appears to be amorphous, but the walls of the cavities are very crystalline : if these cavities are formed by excess moisture this theory is apparently supported : in any case there is apparently a discontinuity of structure near the surface of internal cavities.

Presence of Capillary Canals revealed by the Microscope.—Besides spherical cavities the microscope also shows a certain number of minute canals following tortuous paths through the cement.

The width of these ducts is between one and three-thousandths of a millimetre, or, roughly, forty-millionths of an inch.

The slides showed several canals in the cement, but only one case of a duct entering a cavity. The ducts being very small, even compared to the cavity, the chances of the section being cut at the exact spot where a duct enters the cavity are very small. Hence, although the microscope reveals the existence of these ducts, and proves that ducts do enter cavities, it cannot be expected to prove that all cavities have canals leading to them, although it is highly probable that this is actually the case.

Some indirect evidence on this point is given by taking a block that has one surface ground dead smooth, and smearing this surface copiously with water. If the surface is viewed through the microscope it is seen that the water surface instantly goes hollow and the film quickly breaks over each spot where there is a cavity. Also, if a drop of water is placed in a cavity it quickly runs into the block, and the receding hollow surface can be watched like water running out of a small tank ; a drop placed on the smooth surface of the block, not in a cavity, takes a much longer time to disappear.

Whether or not the mass of the cement is permeable apart from these canals it is impossible to say, but it seems probable that the bulk of the percolation takes place through these ducts, and the cavities form frequent tiny reservoirs in their course.

In fact, the internal structure of the cement may be compared to an extensive system of tube railways, with frequent stations where the size of the tube is greatly enlarged.

A Theory to explain why Absorption takes place at a Decreasing Rate.—The passages and cavities in the cement are initially filled with air under atmospheric pressure, which has to be displaced wholly or partly by the entering water.

Consider, firstly, the case of a block completely submerged in water : The air initially in the block is completely trapped, and, consequently, must be driven by the entering water, through the passages and caverns towards the centre of the block.

Its original volume is thus reduced, causing a continuous rise in internal pressure as the water enters.

The rise of internal air pressure reduces the resultant force causing the inflow of water, and as this resultant force will decrease continuously as more water enters, the rate of absorption must be a decreasing function of the time, which experiment has shown to be the case.

The suggested sequence of events may be compared to a small scale reproduction of what takes place when a sea wave rushes into a cavern that is nearly submerged ; the imprisoned air, becoming highly compressed, resists the entry of the wave. When the wave recedes it helps to eject it, and ultimately bursts out in a cloud of spray.

If the decreasing rate of absorption of the water is due, as suggested, to the compressing of the air that is initially in the block, then it should be possible to make his compressed air eject some of the absorbed water if the external head is removed.

It is difficult to exactly foretell how surface tension forces will act in such a case but it is probable that on the whole they will assist absorption and resist ejection so that it is to be expected that the quantity ejected would be small.

Mathematical Interpretation of Trapped Air Theory.—As a first approximation consider the case of a single closed vessel being filled through a very small pipe, the water being under a constant head " h." Let the volume of air initially in the tank be " V " at atmospheric pressure " P." After time " t " when a quantity of water " q " has entered let the pressure in the vessel be " p."

Then, supposing no change of temperature to have taken place $p(V - q) = PV$. Neglecting surface tension forces, it is easy to show that the total quantity " Q " which will enter is given by the equation $Q(h + P) = hV$; now in these experiments " h " is about $\frac{1}{30}$th of " P," so that, finally, $Q = \frac{1}{31}V$: hence, as the greatest value of $\left(\frac{q}{v}\right) = \frac{1}{31}$, therefore $\left(\frac{q}{v}\right)^2$ etc., can be neglected in comparison with $\left(\frac{q}{v}\right)$.

The resistance to flow through the pipe will vary as the speed of flow, which is equal to $\frac{1}{\pi}R^2\frac{dq}{dt}$, and hence the resistance to flow is given by $k\frac{dq}{dt}$ where k is a constant depending on the viscosity of water and the length and radius of the pipe.

Hence the equation of motion becomes

$$P + h - p = k\frac{dq}{dt}$$

$$\therefore\ P + h - \frac{PV}{V-q} = k\frac{dq}{dt}$$

$$\therefore\ (P + h) - P\left(1 - \frac{q}{v}\right)^{-1} = k\frac{dq}{dt}$$

$$\therefore\ h - \frac{Pq}{v} = k\frac{dq}{dt} \text{ neglecting } \left(\frac{q}{v}\right)^2 \text{ etc.}$$

$$\text{and hence } q = \frac{hV}{P}\left(1 - e^{-\frac{P}{vk}t}\right)$$

It is quite unsuitable to consider the mathematics of an infinite distribution of similar cavities and passages one after the other, but a fair insight into the conditions obtaining in an actual case can be got by considering the case of two and of three tanks in succession.

The result of such a calculation is as follows, for two tanks :—

$$q = 2\,Q\,(1 - \cdot 9e^{-mt} - \cdot 05e^{-7mt}) \text{ where } m = \cdot 4\frac{P}{kV}.$$

and for three tanks is :—

$$q = 3\,Q\,(1 - \cdot 9e^{-nt} - 0\cdot 8e^{-8nt} - \cdot 01e^{-17nt}) \text{ where } n = \cdot 2\frac{P}{kV}.$$

This shows that the terms of the series representing a large number of tanks decrease in value very rapidly, and except when " t " is very small the first term of the series is the significant one.

Consequently there is reason to suppose that the quantity of water entering a block can be represented by an equation of the form $q = Q\,(1 - e^{-xt})$ where " x " is some constant dependent on the number and size of the cavities and canals.

When comparing the porosity of stones or bricks by weighing them after immersion in water, it is apparently important to soak the specimens for many days in order to obtain a true comparison—unless the period of immersion is very long the imprisoned air will not have escaped, and the specimens need not necessarily have attained the same degree of possible saturation.

It is, perhaps, not without interest to substitute numbers in the expression already found and find how long it would take to fill one cavity of the size known to exist in the concrete through one single canal (supposed circular) of the size measured.

Suppose the length of a duct is 1 mm. and its radius $\frac{4}{10^4}$ cms.

$$k = \frac{8e}{100\pi R^4} = \frac{10^{12}}{6} \text{ about.}$$

Take $V = \frac{1}{10^4}$ cub. cm. and $P = 1{,}000$ gms. per sq. cm.

$$\frac{kV}{P} = \frac{10^{12}}{6} \times \frac{1}{10^7} = \frac{10^5}{6}$$

When $t = \frac{3vk}{P}$ the final state will be nearly reached.

Time required $= \frac{10^5}{2}$ seconds.

= 13 hours about.

No doubt in most cases there are several canals per cavity, and this would reduce the time required ; in any case, the time calculated above is of the right order of magnitude.

If the analysis is performed for the case where the applied head is comparable to the atmosphere so that $\left(\frac{q}{V}\right)^2$ cannot be neglected, the curve is no longer a simple exponential, though it is of the same general type : it, however, only differs appreciably in the early stages.

Consideration of Absorption into and Percolation through a Slab exposed on one Surface only to Water Pressure.—Absorption at a decreasing rate into such a slab can be explained on similar grounds, for all the central portions will be surrounded with water and behave in a similar manner to a submerged block.

Also there will be considerable resistance to flow of air in the direction of the thickness of the slab which will all tend to act in the same manner and allow time for the water to enter to varying depths and completely enclose a region.

The Physical Laboratories tests showed that water actually passed through and dripped from the underside at a decreasing rate : it is difficult to see how this can be accounted for in the same way, although perhaps with more knowledge of the distribution of the canals it would be clear.

It would be interesting from many points of view to discover whether the presence of water in the canals causes the small grains to swell and obstruct the passages contraction taking place later when the substance had partly dried off.

It is generally accepted that permeability decreases with age, and it would be interesting to know whether this ageing can be accelerated by the passage of water for long periods.

It is difficult to see how the microscope can be of assistance in tracing progressive internal changes in cavities and canals, although it may, perhaps, assist expert chemists to tell us how to make cements and mortars initially free of these defects ; but until this happy discovery has been made, it would appear that some method of silting up the concrete might be as effective as adding various compounds with the cement before mixing.

DISCUSSION.

Dr. Oscar Faber, in a written communication, said that during the war he had carried out some experimental work for a branch of the Admiralty, in connection with making containers of very small thickness perfectly watertight under great heads of water, and had eventually succeeded in making concrete only 2 in. thick absolutely watertight under 100 ft. head of water. During those experiments the nature of concrete from the point of view of watertightness, which the author had described as little air bubbles connected by capillary canals, was fully investigated and confirmed. His own view was that the theory explained in the paper did to a large extent represent the mechanism, but undoubtedly it was only part of the mechanism, and there were various other important facts without a knowledge of which one could get quite a wrong idea about the whole subject. It did not, for example, explain the fact that if a newly-built reservoir of slightly porous concrete were filled and subjected to pressure from one side the percolation was very rapid at first, and then gradually diminished, until in a few days' time it might have practically ceased. According to the author's theory, once all the air had been expelled from the air bubbles and canals in the concrete, a constant condition of steady flow should follow, but this was not found in practice to be the case. In point of fact, the flow continued at a diminishing rate, and might eventually cease, even when the water was practically free from impurities. It was noticed in such cases where the percolation was reduced to a very small amount that a calcium salt began to be deposited on the outside of the reservoir, from which one was forced to the conclusion that on the inside face part of the cement appeared to be dissolving, and no doubt the diminished flow was largely due to those salts blocking up some of the canals near the outside of the wall. Dr. Faber said that the author had made a mistake in assuming the mass of the concrete to be unaffected by percolation, and to consider that as being practically confined to canals. The error of this, he believed, followed from the experimental fact that when concrete was thoroughly wetted it expanded quite considerably, and subsequently shrank again when dried. This, to his mind, clearly indicated that the water had affected the body of the concrete, not only in the canals. It was also found that when the concrete was thoroughly soaked, the percolation was very much reduced, and this could be partly explained on the assumption that some of the dried colloid enclosed in between the grains of concrete expanded considerably into a gelatinous mass, and tended to block up the canals.

Dr. J. S. Owens, in proposing a vote of thanks to Mr. Moullin, said that the paper had the advantage that it opened up what was to an extent a new aspect of the question of the structure. There were some points in the paper with which he agreed. The method of testing the absorption of water in concrete, in which a small cube is enclosed in an airtight and watertight vessel, could not result in anything but the result shown, i.e., they had a volume of air imprisoned inside the concrete, and the water as it went in had to compress that air. The question of the absorption of water in the block was, therefore, in that case mixed up with that of the compression of the imprisoned air. It was worth remarking that there was no means of escape of that air. In the case of the percolation of water through a slab he did not quite agree with the author's conclusions that the diminishing rate of percolation was also due to imprisoned air. He (Dr. Owens) could not quite see that the statement that the air was under similar conditions to that in the block surrounded by water was correct. The slab was not surrounded by water on all sides, and the air might escape through the lower face, so that he thought they must look for some other cause for the diminished rate of flow, and the obvious cause, he believed, was the contraction of the canals. He used the word "canals" in a wider sense, i.e., there must be passages of some sort, otherwise water could not get in. Perhaps those passages contracted through the expansion of some of the materials composing the slab, these materials contracting again when the water was allowed to dry off. He did not think the explanation was to be found in the compression of the imprisoned air. The last part of the paper was concerned with the micro-structure of concrete and cement, and particular reference was made to cavities of spherical shape. The author had said that he was not clear as to how the cavities were formed, but that from their spherical shape they were presumably caused by drops of excess water. Dr. Owens did not think that was correct. There was something else which occurred, and that was the imprisonment of air bubbles through the process of making the cement or concrete. Those air bubbles would take on spherical shape. The author had perfectly described those cavities, and it was certain, to his mind at least, that they were due to air bubbles. The variation in size was simply a matter of whether there was a large or small volume of air imprisoned. They might be found to be more numerous in the vicinity of particles of aggregate, and that might be explained by the carrying in of air with the aggregate. Dealing with the system of canals or ducts, Dr. Owens called attention to a peculiarity shown in one of the slides, and that was the tortuous shape of these. It struck him as remarkable that such a canal should be tortuous in one plane only. The sections were extremely fine, a thousandth of an inch perhaps. It was too much to ask that a tortuous canal should wriggle about in one plane, and that they should happen to cut a section through that plane; he suggested that it was not a canal. There was another thing which he thought would occur, and that was the formation of small cracks; there were many reasons why cracks should be formed. The question of the effect of the viscosity of the water was one which should be taken into account in percolation experiments; they were dealing with very small passages and very slow rates of flow. The rate of flow of the liquid through the passages depended mainly upon the viscosity of the liquid, and the viscosity varied with the temperature, so that they had also to consider the temperature effect, or rather, change of viscosity due to change of temperature.

Capt. Harrington Hudson said that when explaining the internal structure of concrete as revealed by the microscope, and in particular the spherical cavities, the author had stated that "these cavities are presumably caused by drops of excess water," and that "it would be worth while to see if the number of holes per square cm. is related to the percentage of water used in mixing." This was a point of considerable interest to the engineer, but how did the water content affect the absorption into, and percolation through, the concrete? An interesting series of investigations on tanks for oil storage had recently been carried out by Messrs. Pearson & Smith at the U.S. Bureau of Standards, Washington. Amongst the preliminary tests on water penetration losses were tests of three similar tanks. Each of these tanks was made of 1 : 2 : 4 concrete, but the mixtures were of different consistencies, i.e., 8 per cent., 9 per cent. and 10 per cent. water.

The tanks were dry on the outer surfaces throughout tests of 140 days, so that the question of drip did not arise. He emphasised the fact that the water content in the mixture greatly influenced the absorption into, and percolation through, the concrete. Dealing with the author's reference to absorption into, and percolation through, a slab exposed on one surface only to water pressure, Capt. Hudson said the author had pointed out that the National Physical Laboratory tests showed that water actually passed through and dripped from the under side of the slab at a decreasing rate, although the cause of the decreasing rate was apparently temporary. The initial rate of drip was restored after partial drying of the slab. Later, the author had suggested that with more knowledge of the distribution of ducts in the concrete, this might be explained. Capt. Hudson said that he personally could not see how any distribution of the ducts could account for the phenomena. The temporary contraction of the ducts, due to swelling of the small grains under the action of water, seemed to be a much more likely explanation. He then quoted the following from the report on tanks for oil storage, tested at the U.S. Bureau of Standards :—"In nearly every case the loss curve of any given oil in any given tank has become practically a straight line within two months after the beginning of the test." In other words, said Capt. Hudson, the rate of oil percolation ultimately became constant. The same could not be said in the case of water percolation, which gradually decreased. It appeared, therefore that it was the action of water upon the concrete which accounted for the decreasing rate of drip, and that the arrangement of the ducts would not help to explain the phenomena. Another interesting development was recorded in the report. After about 2½ months, fine cracks were discovered on the outside of the *water* tank, and these did not appear on any of the oil tanks. The tanks and their contents were kept at a fairly uniform temperature, and the only explanation which suggested itself, the report said, was that sufficient compressive stress (apparently due to swelling of the concrete) had developed in the wet concrete of the inside of the water tank to produce tension failure in the dry outer layer. The cracks could not be detected on the inside of the tanks. If concrete swelled gradually under the action of water, said Capt. Hudson, the natural supposition was that the walls of the ducts or canals, being in direct contact with the water, should swell first and thus tend to close up the ducts. He put this forward as a possible explanation of the decreasing rate of drip to which the author had referred.

Mr. C. T. Lewis said that with regard to the porousness of concrete, two interesting papers had been published, one by the Bureau of Standards, No. 58, which was most interesting from the water proportion point of view. When he had those papers about eighteen months ago he had a job in London where it was absolutely imperative that water should be kept out. He had made a series of experiments with the ballast and cement he was getting (the results practically agreed with the American tests), and had found that compression could be reduced by as much as half by an over-plus of water. He had worked this out to very fine proportions, and the work had gone on quite satisfactorily, which went to show that it was the water more than anything else in mixing concrete which was the trouble in causing porousness.

Major Shingleton said he believed it was generally accepted that mixing had much to do with permeability. If the samples were mixed carefully on a piece of glass with a small trowel, there should not be much chance for canals to form. From the practical point of view, the point to consider was the voids and canals in the ordinary 1 : 2 : 4 concrete.

Mr. S. D. Caruthers said he had made experiments on the percolation of air through concrete. He had a tube of about ½ in. diameter, put a cement cork in the end of it, and filled it with water to within an inch of the cork. He had expected that the water would have dropped down from the cork but had found that it did not. On the contrary, after the water had been in the tube for about four months, instead of falling, it had risen about ¼ in. The water was gradually rising, not day by day, but month by month. He knew perfectly well that if he had put the water in contact with the cork it would never have left the cement ; he was quite certain that the affinity between the water and the cork would be sufficient to retain it airtight, and it was for that reason he had left a space between the cork and the water. The result had upset all his theories in connection with the percolation of air through the cork. The next thing he did was to dip an ordinary cork in water and put it on the cement cork, and the water could be seen through the glass, running right down the cork, like the wetting of a piece of sugar. The whole thing was a perfec' enigma to him. It could be explained in two ways. It could be said that the amount of air that was being lost between the cork and the water was being absorbed by the water underneath. It could also be explained by suggesting that the density of the air in the tube was of a different character from the outside air, and so there would be diffusion of gases. Moist air being lighter than dry air, it ought to diffuse more, and trickle through the cement. There was one other observation. If a block of concrete is made and left to dry for a few days, it would lose a great deal of weight. This does not refer to the losses during the first day, but between, say, the end of the first week and the end of a month. Then, if put into an oven and left there for a long while, it would come to a constant weight. There must be a great number of cavities in the concrete to let out that water, and all those cavities must be inter-connected, and would take in further water.

THE LECTURER'S REPLY.

Mr. Moullin, replying to the discussion, dealt with the difficulty of understanding why the water should drip from the under side of a slab at a decreasing rate, which had been referred to by both Dr. Owens and Capt. Harrington Hudson. It was worth while, he said, to distinguish between absorption from the top and drip from underneath. He could not see how it could be explained in the manner in which they proposed it was possible. Absorption from the top was largely, he believed, a matter of dimensions of the blocks. With regard to the question of whether or not small spherical cavities were formed by air bubbles or by water, there was no proof of it being one or the other. It seemed to him that while a thing was in a fluid state, it was more likely that they would expect that if there were air bubbles the air would easily escape. He had suggested that after it was set the resistance to the flow of air through a depth of a slab may affect the flow of water behind it. It was difficult for him to understand how that should be, say, in the fluid state. Coming to the question of making allowance for variation of viscosity of the water with temperature changes, the changes of temperature were not more than + or — 1 deg. The tests were carried out at ordinary room temperatures, and probably the range of temperature within the block was even less. It was probably rather a secondary matter to make an allowance for change in viscosity due to temperature. As to whether the ducts he had mentioned were actually ducts or cracks, he was not quite clear how Dr. Owens discriminated between the two. That is to say, if Dr. Owens had suggested that the crack had come about after the making of the microscopic slide—of course, that possibility had struck him long ago—he believed it was improbable that it was so, due to the position of the duct and the cavity in the slide, and also to the fact that they could see these ducts in the centre of a batch of set cement, not round a cavity, where one presumed they would come. However, if it were possible to prove that those things were cracks he would be very glad to know, because it was a matter upon which they could not decide without definite proof. It was quite possible they might be actual ducts. With regard to Capt. Harrington Hudson's curves, it was evidently established that the absorption and percolation curves were exponential to a high degree of accuracy. Such a point, he believed, had not been established before, and might possibly be of use. On the question of absorption of water into a block completely surrounded by water, the explanation offered by Capt. Harrington Hudson might meet the difficulty, but he would leave it to others to decide whether it was important or not.

NEW BOOKS

AT HOME AND ABROAD.

A short summary of some of the leading books which have appeared during the last few months.

The Failure of Metals under Internal and Prolonged Stress.

Published by The Faraday Society. Price 10s. 6d. net.

This volume is a record of a general discussion held jointly by The Faraday Society, Institution of Mechanical Engineers, The Iron and Steel Institute, The Institute of Metals, The North-East Coast Institution of Engineers and Ship Builders, The West of Scotland Iron and Steel Institute, and The Institution of Engineers and Ship Builders in Scotland.

It contains five papers of a general character dealing chiefly with the failure of metals, with a most valuable introductory address by Dr. W. Rosenhain, followed by a general discussion in which all the more important chemists and physicists interested in the matter took part. Section 4 consists of seven important papers on failures in steel and discussions thereon, followed by four papers on failures in brass and discussions.

The whole book is one of extraordinary interest and importance, and it is really impossible in a short review to do justice to a book of some 215 pages full of diagrams and photographs, particularly when so many papers and subjects are dealt with.

Metals are to be considered as crystals with amorphous material between the crystals. According to Sir Alfred Ewing failure at low temperatures consists of slipping on planes within the crystals and at high temperatures the material gives way by the viscous yielding of the amorphous inter-crystalline layer. Under certain conditions, however, the amorphous material between the crystals fails at low temperatures and is responsible for the breakdown of the whole structure, and these conditions appear to be principally chemical corrosion, internal stress and external stress, but by far the most important cases occurred as a result of internal stresses and conditions where internal stresses and chemical corrosion are combined. Internal stresses may result from a variety of causes of which, however, the most important are unequal cooling, and where work is done on the material at low temperatures such as rolling, punching, drawing, etc.

It is quite a common thing for brass rods, for example, to develop flaws during storage, the flaws taking the form of definite cracks occurring between the crystals, and susceptibility to this kind of failure is greatest in the case of brasses which are hard either as a result of chemical constitution or as a result of rolling, wire drawing, or other forms of work. Of 2½ million brass rods inspected by Woolwich, it appears that about 4 per cent. of certain sizes of rods of a particular specification which called for a yield point of 8 tons, maximum of 20 tons, elongation of 12 per cent. occurred owing to fracture by cracking. It will be seen from this that the subject is one of by no means academic interest only, and in fact, any brass worker will confirm the danger of failure during storage. The important thing to us is perhaps that *failure is associated with hard materials* whether the hardness is due to chemical composition, or wire drawing, etc., and that the danger can be removed by annealing, in other words, by reducing the material to a soft condition.

To us perhaps the most interesting portions of the paper are those which deal with steel, and here exactly the same thing is found. Apparently many rails in America develop internal stresses which frequently cause fracture due to exactly the same causes, and it is significant that over here where a softer steel is used these failures are almost unknown.

A large part of the earlier papers deal with the question as to whether the failure of the material between the crystals is due principally to chemical or physical agencies acting in combination with the severe internal stresses always associated with hard materials, and as many of the experts differ we will not here go into this question, except by remarking that certain chemical salts appear to dissolve the material between the crystals so rapidly as to entirely destroy hard metals in the course of a few minutes by separating it up into its component crystals.

The book has an important bearing on the advisability in engineering structures of using hard steels whether such hardness is due to chemical composition or due to wire drawing and other forms of work. Undoubtedly the material most generally used for structural work is mild steel which has the advantage of softness and is therefore not likely, judging by the experimental evidence given in the present work, to suffer by prolonged external stresses under ordinary conditions, nor is it likely under the conditions under which it is normally used to become so hard as to develop severe internal stresses which would make it liable to cracking and in course of time to fracture. If, however, mild steel plates are, for example, punched cold it has been recognised by practical engineers that the material surrounding the hole becomes hard and liable to sudden fracture in course of time, and therefore good specifications for riveted work have long insisted that either holes are to be drilled or else punched holes are to be reamered afterwards so as to remove the hardened material, though this latter specification is in any case not so good as drilling.

Comparatively recently there has been an effort on the part of many engineers, particularly reinforced concrete engineers, to use a much harder steel—in some cases obtained by an increased carbon content, and in other cases obtained by cold twisting or cold wire-drawing,—and then to use increased working stresses raised in proportion to the increased ultimate stress on the material.

In my opinion, this has generally been done in ignorance of the well-founded dangers which led older engineers to stick to the softer steel, though they recognised that a little more would be needed.

Any one reading the present work with an open mind will come to the conclusion that this is to invite a very grave risk of fracture and inter-crystalline corrosion under prolonged stress, and in fact, renders the material subject to additional dangers from which the mild steel is free and from which it would appear obvious that these harder materials, if allowed in structural work, ought to be used with considerably greater factors of safety than the mild steel. This conclusion appears inevitable if the overwhelming experimental evidence supported by the very first authorities on these subjects are to be given the value which, in my own opinion, they undoubtedly deserve.

O. F.

Mechanical Testing. Volume I. Testing of Materials of Construction. By R. G. Batson, M.Inst.C.E. and J. H. Hyde, A.M.Inst.C.E., both of the National Physical Laboratory.

Chapman & Hall. Price 21s. net.

This book of some 400 pages and some 250 diagrams is quite one of the best works on the subject I have seen.

Its scope and usefulness are really rather greater than perhaps its title would indicate, because in addition to descriptions, theory, and uses of testing machines of every conceivable kind, there are excellent chapters on the stress, strain, elastic constants of all kinds, their inter-relations, etc.

The book also gives the results obtained with the various testing machines on different materials, which again might not be assumed from the title.

The present volume is probably the one which will interest us most, and deals with load, strain, stress and elasticity, properties of materials, testing machines, grips and shackles and calibration of machines, elongation and contraction of area under tensile test, commercial testing, mechanical tests of hard drawn wire, testing cast iron, influence of shape and time on properties of materials, measuring instruments for determination of elastic constants, autographic recording apparatus, repetition of stress, combined stresses, fatigue ranges, alternating bending tests, hardness and abrasion, impact and notched bars, effect of temperature, timber testing, testing stone, brick, cement, road materials, limes and cements.

It will be seen that while any one concerned with testing will find the work extremely useful, its usefulness extends to a greater scope and includes those who are interested in an accurate and scientific knowledge of the properties of materials.

The book is first class throughout and to be highly recommended.

O. F.

THE "IDEAL HOME" EXHIBITION.

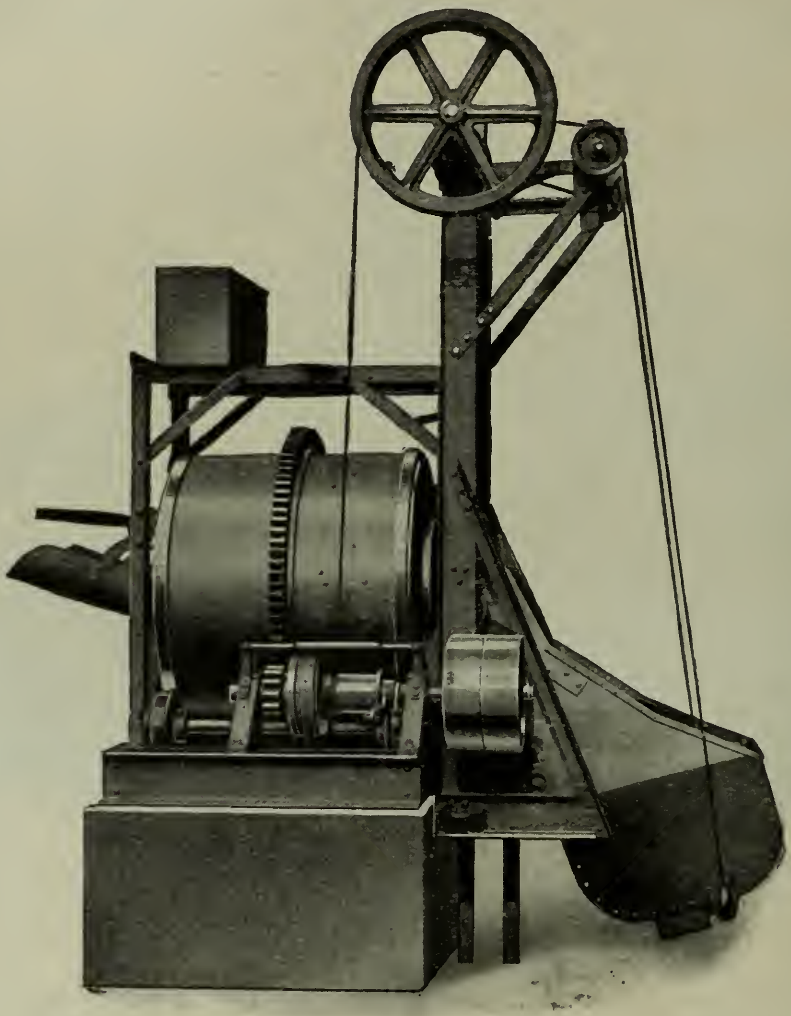
If he were unfamiliar with the true facts of the case, a visitor to the "Ideal Home" Exhibition held at Olympia last month would undoubtedly have come to the conclusion that the housing problem in this country had been solved, for the exhibit of methods of construction and building materials which formed so conspicuous a feature of last year's show had largely given place to a display of furniture and fittings and decorative materials. But although the attractive new cottages and bungalows were missing, the acuteness of the housing shortage was forcibly brought home by the only exhibit in the form of a complete dwelling-house, namely, a reproduction of a typical Lanarkshire miner's cottage, in all its squalor and ugliness, erected under the direction of Messrs. Herbert C. Ellis & Clarke, architects.

Houses at Liverpool.

The following account of the exhibition is confined solely to the exhibits dealing with the uses of concrete and concrete machinery, and only those which were shown for the first time are dealt with at any length.

COLOURED CONCRETE BLOCKS.

Besides their well-known series of machinery for use in concrete work, such as block-making machines, stone crushers, mixers, elevators, etc., *Messrs. Winget, Ltd.* (24, Grosvenor Gardens, S.W.1), showed a selection of concrete blocks, made on a "Winget" machine, which had been treated on the surface with attractive colours. These blocks have been used with considerable success on the Liverpool housing scheme under the direction of Mr. F. E. G. Badger, Housing Director to the Liverpool Corporation (cottages in which such blocks have been used at Liverpool are illustrated above), and in a pair of houses at Welwyn Garden City, for which Mr. Leonard Martin, F.R.I.B.A., is the architect. The blocks are in a variety of colours and tints, including black, white, silver-grey, sandstone, red, yellow and green, and the Liverpool scheme shows that the use of such colours with discrimination and taste can give a very attractive appearance to what might otherwise be a drab and monotonous row of houses. The colouring is applied when the blocks are being made on the machine, and thus the expense of double handling is obviated; it is claimed that these blocks for a given amount of walling cost no more than selected common brickwork. In the Liverpool scheme plastering has been dispensed with by the use of smooth-faced coloured blocks for the internal walls.



Shows a "Zenith" ½-yard Concrete Mixer arranged for Belt Drive, and fitted with Side Loader.

CONCRETE MACHINERY.

The "C.D.L." method of concrete wall building was demonstrated by the *Concrete Dwellings (Parent Company), Ltd.* (1, Cartaret Street, S.W.1). This system of building a cavity wall by means of a travelling mould has already been described in our pages, and has been used in the erection of houses at Welwyn and other places.

The Australia Concrete Machinery and Engineering Co., Ltd. (606–7, Salisbury House, E.C.2), showed the well-known "Australia" block-making machine and the "Tonkin" mixer in operation, both of which now embody several minor improvements. On this stand was shown for the first time a new product of this firm, the "Speedy" crusher. This is a belt-driven machine, designed for crushing clinker, bricks, and shingle. The crusher and engine are erected as a complete unit on a portable stand, or the crusher may be obtained as a separate unit. The machine appears to be strong and capable of a good output.

THE "UNIVERSAL" BLOCK MACHINE.

The "Universal" hand block-making machine was exhibited for the first time on the stand of the *Stronghold Cement Block Construction and Machine Co., Ltd.* (34–35, Norfolk-street, W.C.2). This machine, which we illustrate, is constructed mainly of timber, and strengthened with steel. The blocks are made with the face to the front of the machine, and, with the use of liners, practically any shape of solid or hollow block, slab, angle or moulded block can be produced. The pallet containing the finished block is raised by the depression of the lever at the side, and by a simple turning movement the pallet may be rested on the edge of the top of the mould whilst the block is removed; this movement is obtained by a sleeve action on the pillar supporting the pallet.

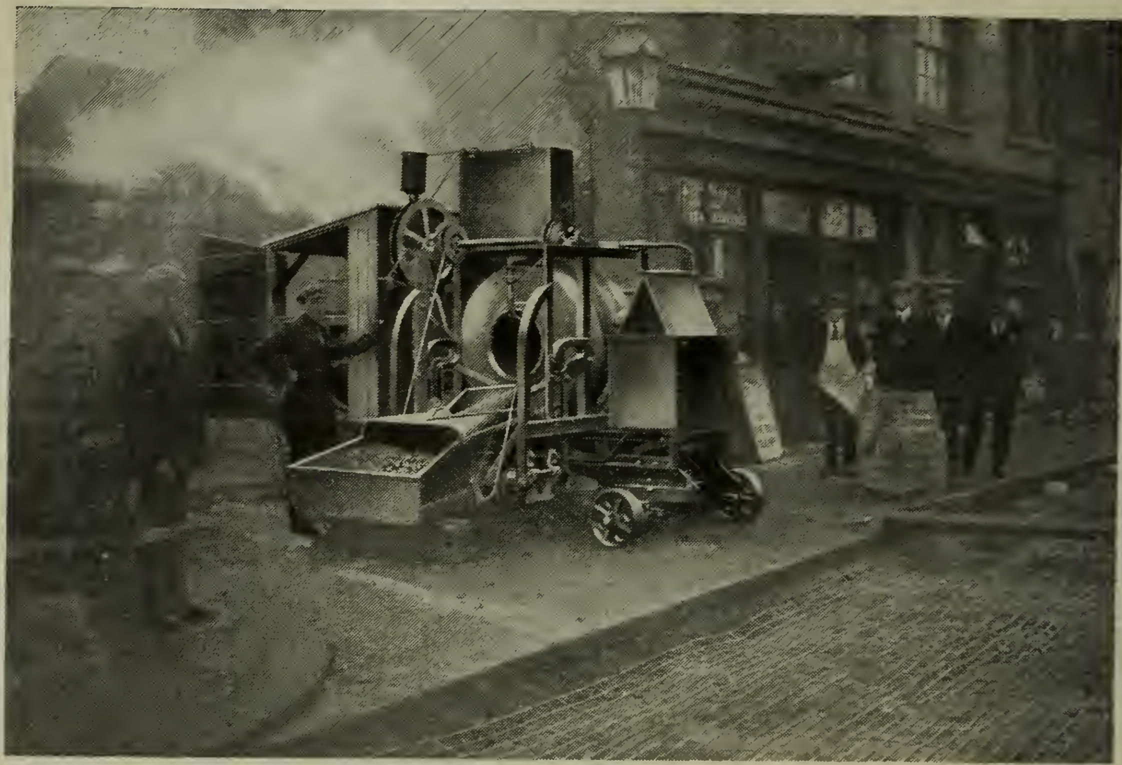
GENERAL.

"Waterex," a liquid waterproofer for concrete, brickwork, etc., was shown by *The Waterex Co., Ltd.* (104, High Holborn, W.C.1).—"Colemanite" liquid waterproofer (formerly known as "Anti-Hydro") and "Atlas White" Portland cement were exhibited by the Adamite Co., Ltd. (Regent House, Regent Street, W.1.)

TRADE NOTE.

Messrs. Trent Concrete, Ltd. (Netherfield, Nottingham), are now using the "Insley" mast hoist plant in the construction of a power-house for The Nottingham Colwick Estates, Ltd., for supplying power to the various factories on the estate. We are informed that the plant is giving complete satisfaction, the average number of batches placed being 40 per hour. This combination mast hoist and elevator comprises a wood mast built by the contractor on the job, 8 cubic feet capacity hoist bucket, head frame, top sheaves and angle guides and such lengths of chute as are required. After receiving its load from the mixer, the bucket is hoisted and automatically dumped by a lever striking the head frame, allowing the concrete to flow out by gravity. When the hoist line is slackened, the bucket gate closes by its own weight, tight closing being ensured by springs. The material elevator is interchangeable with the bucket, and consists of a platform frame 3 ft. by 4 ft. The contractor puts on his own flooring to suit his particular requirements.

Enquiries should be addressed to Messrs. Christmas, Hulbert & Walters, Ltd., Caxton House, Westminster, S.W.1.



The Victoria CONCRETE MIXER

Self Contained Portable Mixer.

The above illustration shows one of our petrol driven half yard Victoria Mixers mounted on road wheel truck with swivelling fore-carriage, and is the type we supply in large numbers for general contracting work. Smaller and larger machines are supplied, ranging in capacity from 3 to 54 cub. ft. of mixed concrete per batch. Particulars of the large models are contained in our catalogue M.D. 103, and of the small models M.D. 105. We also manufacture the Dri-crete block making machine for use with these smaller mixers. Please write for the catalogue in which you are most interested.

STOTHERT & PITT LTD

MIXER DEPARTMENT

ORCHARD STREET WESTMINSTER S.W.1

Memoranda and News Items are presented under this heading with occasional editorial comment. Authentic news will be welcome.—ED.

The Building Trades' Exhibition.—A perusal of the list of exhibitors at this year's Building Trades' Exhibition (April 11 to 27) indicates that the interest this event holds for all concerned with the building and allied trades will be as great this year as last, when the show was quite an exceptional one. The available space has been completely taken up, and the exhibits of the following firms will no doubt be of special interest from the point of view of those connected with the concrete industry :—

D. Anderson & Son, Ltd. ; Australia Concrete Block Machine Syndicate, Ltd. ; Bell's United Asbestos Co., Ltd. ; R. W. Blackwell & Co., Ltd. ; British Everite & Asbestilite Co., Ltd. ; British Fibrocement Works, Ltd. ; British Roofing Co., Ltd. ; Builders' & Contractors' Plant, Ltd. ; Building Products, Ltd. ; Cement Marketing Co., Ltd. ; Climbing Steel Shuttering Co., Ltd. ; Concrete Dwellings, Ltd. ; Concrete Utilities Bureau (where literature and information regarding the uses of cement and concrete will be available) ; Expanded Metal Co., Ltd. ; Fawcett Construction Co., Ltd. ; The Ironite Co., Ltd. ; Johnson's Reinforced Concrete Engineering Co., Ltd. ; Kerner Greenwood & Co., Ltd. ; J. A. King & Co. ; Kleine Patent Fire-Resisting Flooring Syndicate, Ltd. ; F. McNeill & Co., Ltd. ; Moler Fireproof Brick & Partition Co., Ltd. ; Ransome Machinery Co. (1920), Ltd. ; Self-Sentering Expanded Metal Works, Ltd. ; Sharp, Jones & Co. ; Siegwart Fireproof Floor Co., Ltd. ; G. R. Speaker & Co. ; Stothert & Pitt, Ltd. ; Torbay & Dart Paint Co., Ltd. ; Tourba Construction Co., Ltd. ; Tuke & Bell, Ltd. ; Turner Brothers' Asbestos Co., Ltd. ; Vickers, Ltd. ; Vulcanite, Ltd. ; R. G. Whitaker, Ltd. ; Henry Wilde, Ltd. ; The Wilfley Co., Ltd. ; Winget, Ltd.

Graphs and Alignment Charts for the Design of Reinforced Concrete Work.—In response to a number of enquiries regarding these graphs and charts by Mr. Jos. Dawson, which appeared in our February issue, we are asked to state that Mr. Dawson is prepared to supply black and white copies of the original graphs and the letterpress at a charge of 10*s.* per set.

TRADE NOTES.

The Considère Construction Co., Ltd., who for the past fourteen years have developed in the British Isles the Considère System of reinforced concrete design, propose pooling resources with the French firm of Pelnard-Considère & Caquot, with a view to increasing the scope of their business and giving their English clients the benefit of the unique experience which their French colleagues have had during the past few years.

Reinforced concrete work in France has been developed to an enormous extent and Messrs. Pelnard-Considère & Caquot have themselves designed reinforced concrete work to the value of well over £4,000,000 in the past eight years, covering power stations, bridges, industrial and other buildings, etc.

TENDERS ACCEPTED.

BURRY PORT.—The Burry Port Urban District Council has accepted the tender of Mr. H. Bowen Jones, of Burry Port, for the erection of twenty type " B " houses on the Newfoundland site, for the sum of £11,100. Other tenders received were :—T. Hall (Haverfordwest), £10,500—" Calway " system of concrete construction ; Hughes & Samuel (Pwll), £10,870 ; Building Guild (Cardiff), £11,403 ; J. J. Glayfield (Stroud), £11,483 10*s.* ; Walter Jones & Son (London), £12,175 ; J. Charles & Son (Llanelly), £13,700 ; J. Evans (Burry Port), £14,500—£30 per house less if built on " Calway " concrete system ; W. Morgan (Llanelly), £15,000 ; Gathen Building Co., Ltd. (Llanelly), £15,750 ; J. Williams (Llanelly), £16,019 17s. ; W. Williams (Llanelly) £16,660.

CARDIFF.—The tender of Messrs. C. Parker & Co., at £499, has been accepted by the Cardiff Town Council for finishing twenty-four concrete houses.

LONDON (BETHNAL GREEN).—The Bethnal Green Borough Council has accepted the tender of the British Reinforced Concrete Engineering Co., Ltd., for five rolls of "No. 9 Fabric" reinforcement, at £21 per roll.

LONDON (EAST HAM).—The East Ham Borough Council has accepted the tender of the Walker-Weston Co., at 5*s*. 3*d*. per sq. yd., for the supply of reinforcement for the bio-aeration tank at the Sewage Works.

WALLASEY.—The tender of Mr. J. A. Milestone, of Wallasey, has been accepted by the Wallasey Town Council for laying 1,600 yds. of reinforced concrete, for the sum of £693 6*s*. 8*d*.

PROSPECTIVE NEW CONCRETE WORK.

ADVIE.—*Concrete Bridge.*—The construction of a concrete bridge across the river Spey, at Advie, at a cost of about £5,000, is to be put in hand at once by the Moray County Council.

BELFAST.—*Concrete Jetty.*—A new jetty, in reinforced concrete, is to be constructed by the Belfast Corporation.

BOURNEMOUTH.—*Bridge.*—A proposal is on foot for the erection of a new bridge over the river Stour, for the Hants County Council.

BRAZIL.—*Port Improvements.*—The Brazilian Government has decided to carry out extensive improvements at the port of Brazil, at a cost of about £300,000.

BRIDLINGTON.—*Road.*—A new road, to cost about £37,000, is to be constructed from Bridlington to Carnaby by the Bridlington Town Council.

CAMBRIDGE.—*Sewage Works.*—Application has been made to the Ministry of Health by the Cambridge Town Council for sanction to a loan of £36,500 for laying out sludge beds, etc., at the Sewage Works.

CLEETHORPES.—*Open-air Bath.*—An open-air bathing pool is to be constructed by the Cleethorpes Town Council, at an estimated cost of £20,000.

FRASERBURGH.—*Harbour Extensions.*—Extensions and improvements at the harbour, at a cost of £31,250, are proposed to be carried out by the Fraserburgh Town Council.

HASTINGS.—*Concrete Groyne.*—Application has been made by the Hastings Town Council to the Ministry of Health for sanction to a loan of £1,280 for the construction of a concrete groyne.

HASTINGS.—*Reservoir.*—A proposal of the Hastings Town Council to construct a new reservoir, at a cost of £6,470, has been the subject of an inquiry by the Ministry of Health.

HULL.—*Drain-Bridges.*—The Ministry of Health has sanctioned the borrowing by the Hull Town Council of £36,000, principally for the construction of bridges over drains.

KIRKCALDY.—*Sea Wall.*—A sea wall and esplanade are to be built by the Kirkcaldy Town Council, at an estimated cost of £120,000.

LEAMINGTON.—*Road.*—The construction of a new road between Leamington and Warwick New Road, at a cost of £11,000, has been approved by the Ministry of Transport.

LITHERLAND.—*Road.*—A new road is to be constructed by the Litherland Urban District Council, at a cost of £38,660.

NEWBURY.—*Concrete Paving.*—The Newbury Town Council has adopted a proposal for the improvement of the public baths, including the laying of 400 superficial yards of concrete paving.

ROTHERHAM.—*Sewage Works.*—Extensions to the sewage disposal works at Maltby are to be carried out by the Rotherham Urban District Council, at a cost of £23,943

SCUNTHORPE.—*Reservoir.*—A new water supply scheme, including the construction of a 1,000,000 gallon reinforced concrete reservoir, is to be carried out by the Scunthorpe Urban District Council.

SKEGNESS.—*Sewage Works.*—A scheme to modernise the town's sewage disposal works, at a cost of £15,500, has been adopted by the Skegness Urban District Council.

SPENNYMOOR.—*Sewage Works.*—Sanction has been granted by the Ministry of Health to the borrowing by the Spennymoor Urban District Council of £12,720 for sewage works.

STAINLAND.—*Reservoir.*—The Ministry of Health has held an inquiry into an application of the Stainland Urban District Council for sanction to borrow £3,000 for the enlargement of the reservoir.

SWANSEA.—*Dock.*—It is proposed to construct a new dry dock at King's Dock, Swansea, at a cost of between three and four hundred thousand pounds.

NEW COMPANY REGISTERED.

W. E. THOMAS & CO., LTD. (179867). Registered February 21. 456a, Wandsworth Road, London, S.W. Manufacturers of concrete blocks and slabs. Nominal capital, £1,000 in 1,000 £1 shares. Qualification of directors, 1 share; remuneration, to be voted by Company. Directors to be appointed by subscribers.

RECENT PATENT APPLICATIONS.

151,991.—Société Bonnet Aîné et ses Fils: Concrete block-making machines.

153,316.—G. C. Bartram: Pipes, tunnels, reservoirs, and other structures of reinforced concrete.

159,856.—Société Bonnet Aîné et Fils: Concrete block-making machines.

170,595.—R. Hofler and S. Renyi: Building blocks.

174,399.—A. P. L. Snarp and F. E. Walford: Construction of concrete slab buildings.

174,416.—J. W. Lee: Wall construction.

174,451.—A. Melzer: Construction of concrete walls *in situ*.

174,458.—N. S. Chedburn and W. R. Chalmers: Method of securing scaffolding to concrete walls.

174,665.—E. Airey: Internal wall construction.

174,668.—T. K. Webster and W. E. John Roofing and walling material.

174,729.—T. G. Davidson: Concrete wall construction.

174,740 and 174,748.—T. A. Brown and C. Walker: Concrete blocks.

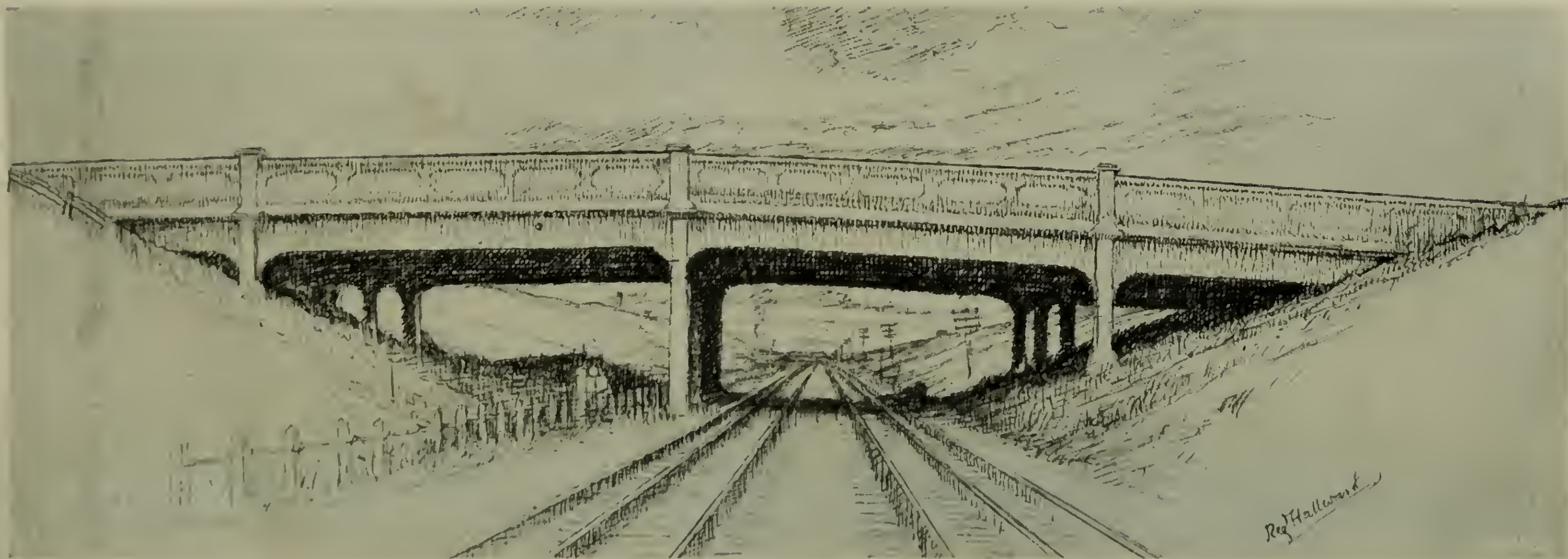
174,792.—M. Galke and Deutsche Leicht-Beton-Massivbau Industrie Ges.: Reinforced concrete buildings.

175,087.—D. Brown: Concrete wall and building construction.

175,105.—J. B. Harvey: Concrete block-making machine.

175,128.—H. C. Badder, S. F. Burrows, and H. L. P. Allender: Moulds for concrete wall construction.

Side View.



Front View.

Reinforced Concrete Bridge between Ealing and Wood Green (G.W.R.).

(*See page* 293)

Vol. XVII. No. 5.
May, 1922.

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 5. LONDON, MAY, 1922.

EDITORIAL NOTES.

THE ARTISTIC POSSIBILITIES OF CONCRETE.

CONCRETE has taken so large a part in building during recent years, and can give such a good account of itself, not only as regards strength and economy in working but also in the possibilities it discloses of further development—being at no disadvantage as regards appearance and permanence with other materials—that it suggests possibilities of new treatment of great importance to the future. The very fact that we have not been primarily concerned with its artistic side, industrial conditions having governed its use so much, has given it an advantage over other materials employed for building purposes which carry a longer tradition of use and wont. This has proved a very good thing, because the use of the material is not burdened by so many precedents. There is prevalent a very mistaken idea that concrete spells materialism and is the expression of it, and that it cannot accommodate itself to that more human and artistic side which has been identified with brick, timber, and stone. No doubt its use during the war was concerned with this side more than with æsthetics, but an imagination disordered enough to suppose that this enclosed all its scope, and that it was limited to industrial use only, would no doubt picture to itself rather ruthless hard-faced men trampling on the sensibilities and on all those traditions of beauty that building materials of more general use carry with them. Nothing could be farther from the facts. Some of the best buildings done in recent times are built of concrete. It is perhaps unnecessary to recall the large Government building in Exhibition Road, South Kensington, which has been the recipient of so much praise from architects and people of discernment on account of its successful construction; it is regrettable that it should be the intention of the Government to cover the whole of it in brick, which at such a time of financial stress seems quite unjustifiable.

Many making use of our suburban lines will be acquainted with the very successful foot and other bridges built of concrete crossing the lines at different places, having quite their own character, and in many ways including a certain beauty growing out of the right use of the material and the success of the design. In the fact that the use of concrete is unburdened by tradition, that it has so often been looked upon as a material of use and not of beauty, far from being any cause of injury has demonstrated to us that the necessities arising out of the war have brought us back to first principles. Necessity—not materialism—is the mother of invention, and we may confuse the one with the other. The war compelled us to forsake mere custom, use and wont. Scarcity of materials created new ones. The same cause brought about a great development in those already in use, and concrete above all others has justified itself as a material the potentialities of which extend beyond any present use made of it. There has accompanied the use of concrete a new approach to building appropriate to itself, the results we admire being due to its own resources and not to any admixture of conventional character. Plainness, bareness even, if you will, limitation to the actual requirements—these are not a defect but the necessary foundation of a genuine and vital architectural style. Nor is it pressing the matter too far to see also the æsthetic side, to see more than the utilitarian and economic necessity which are the right foundations of its use.

There is a sort of metamorphosis going on (in which concrete is taking perhaps the most important part) from the tyranny of the five orders and obsolete survivals which have held the art of building tongue-tied. If our objects in building are such now as are more strictly concerned with practical needs outside of æsthetic preconceptions, we shall find—for such is the strange contradiction—the very beauty and æsthetics which we assume to have left behind coming through our buildings again because we shall have got back to fact—shall have returned to ourselves, and no longer robing ourselves in the cast garments of the past we shall find a garment more truly vital, and our own. There is no conscious repudiation of the historic past in the recognition of our own needs. A bad material is that which in its application will not secure for us the purpose for which it is used. This cannot be said of concrete, and visions of all kinds of new uses lying in so adaptable a material present themselves to us.

We happened to visit the stables of a country house built in concrete some fifty years ago, we believe, by Sir Arthur Blomfield. At that time the concrete block was not used, but the concrete was poured between wooden shuttering, which was removed after it had set. In this stable, as showing how dry and damp-resisting these concrete walls are, some paintings in true fresco were made on the walls inside the stable to test the durability of the material. We saw these paintings only the other day, which were, after so many years, in perfect condition, no trace of any damp being discoverable. Where walls are built up in this way the wood leaves its impression on the wall surface when removed, but there is nothing unpleasant in the appearance, and there is hardly any objection to that which expresses and does not hide the construction.

What has yet to be added to the use of concrete is a greater sense of the possibilities lying in it for construction, in which æsthetic considerations are important, and we foresee much scope for its expansion in this way. Great architectural possibilities growing out of the material and really expressing it, which are wholly the evocation of its own spirit, should produce a style of architecture which yet does no violation to the past because it is the projection of our own character and of our own time and of its needs, which are not those of any other age.

Elsewhere in this issue we give some designs which are, we think, very suggestive of what may be obtained in the way of artistic effect in domestic architecture by the use of carefully-selected colour judiciously disposed on the walls. In these days no doubt the question of cost will be raised, but as most of the colour is in the structural units this should be practically negligible.

INDUSTRIAL TRAINING.

At the first of the conferences held at Olympia during the Building Trades' Exhibition under the auspices of the Concrete Institute (which we report on another page), some strong arguments were put forward in favour of extending the facilities at present available for training those engaged in supervisory capacities and craftsmen in the concrete industry. We have consistently advocated the inauguration of a system of education which would confer a definite status on those employed in the industry, and are glad to note the statement of the President (Mr. E. Fiander Etchells) that the Institute is seriously considering some such proposal, which we are sure would be welcomed, not only by employers and employed, but also by reinforced concrete designers, on the efficient and accurate carrying out of whose specification the soundness and stability of a building, road or other structure so much depends. We are glad to note, also, that our suggestion last month that a certificate of competency be granted was endorsed by the President and other speakers, for the possibility of obtaining such a hall-mark would be a great incentive to those eligible to take up a course of training. We are inclined to disagree with the suggestion that a time of depression is an unpropitious one in which to start such a scheme, on account of the fear that all those who were trained would be unable to find employment, for surely there is a sufficient number already in the industry to fill all the classes that could be formed in the immediate future. If the men already in the industry were trained they would form a nucleus of efficient men who would be available when industry revives, and, as these men would undoubtedly obtain employment in preference to untrained men, they would form an object lesson to new-comers on the benefits to be derived from systematic training. Whatever the scheme decided upon, we hope it will be put in operation without undue delay.

ROADS AND MODERN TRAFFIC.

At the second conference, Dr. Oscar Faber dealt very fully with the subject of concrete roads, and advanced the claims of this type of road in a convincing manner. While expressing his conviction that the concrete road would be the road of the future, he performed a useful service in giving his opinion, derived from practical experience, on some of the methods to be followed if such roads are to be entirely satisfactory. His suggestion that the haulage of heavy loads on narrow steel tyres should be prohibited by legislation is one which should be taken up with the Ministry of Transport, for the damage caused by such traffic is not confined to concrete roads only but its effect is to be seen on all roads of whatever material they are built. The Highway and Locomotive Act of 1878 provides that where expenses in excess of the normal cost of maintaining a road are caused by "extraordinary" traffic (i.e., traffic which damages a road more than the traffic which could reasonably be expected to use such a road, or the customary traffic on the road), the cost of the extra repairs necessitated by such traffic may be recovered from the owners of the vehicles causing the damage, but the difficulty is to prove to the satisfaction of the court that the traffic causing the damage is "extraordinary." When the Act and the amending Act of 1898 were framed, the weights on the roads were limited by the teams of horses by which they were drawn; steam and petrol wagons, by which very great loads can be carried, were not contemplated, and roads could be built which would carry without any serious ill-effect practically any load to which they were likely to be subjected. Heavy tractors and agricultural machinery are, however, now part of everyday life, and the tendency will probably be for their size and weight to increase rather than to decrease. Heavy vehicles and machinery which are necessary for the carrying on of industry can no longer be termed "extraordinary" except in relation to the horse-drawn traffic for which the majority of roads in the country were designed, and the roads of the future will have to be designed to bear them. The extensive use which is being made of reinforced concrete in the arterial roads now under construction indicates a realisation on the part of the leading road engineers that concrete roads are the most suitable for carrying present-day traffic, but, as Dr. Faber pointed out, if weights of six or seven tons are to be borne on steel tyres, nothing but a steel road surface will suffice. The solution seems to lie in the use of rubber tyres for heavy vehicles, and this might be made compulsory without any great expense to the owners; in fact, tests have been made which show that the cost of the tyres is recouped in a very short time by the reduced wear and tear of the vehicles and the lower tractive effort required. So much money is now being spent on the construction of new roads and the reconstruction of existing roads that it seems to be unnecessarily adding to the burden of the taxpayer and ratepayer to permit them to be used as soon as completed by traffic which no road can reasonably be expected to bear.

ASBESTOS CEMENT AS A DECORATIVE MATERIAL.

One of the most noticeable features of the Building Trades' Exhibition at Olympia last month (a review of which is given in this issue) was the great strides made in the use of asbestos cement in various forms for both exterior and interior purposes. The value of this material for the walling of small buildings, and the advantages it possesses for interior wall linings and ceilings in obviating the necessity to employ that *rara avis* the plasterer, have been realised for some time, and it is being extensively used for these purposes. On the stands of the manufacturers of this material were to be seen specimen panels both painted and grained to such exact imitations of wood that the difference was unnoticeable except on very close inspection, and some realistic reproductions of Gothic carving moulded from this plastic material were exhibited. Apart from these specimens, in which the application of the colour is an additional process, some samples in which the colour is obtained in the course of manufacture caused one to wonder whether this is not the direction in which lies the future of the material as a medium of construction which requires no further decoration, with a resultant saving in cost. At present the efforts in this direction seem chiefly confined to utilitarian purposes, such as tiles, and the carrying on of the familiar red of rain-water goods in the new material, but further experiments would probably result in the production of attractive surfaces in a variety of shades which would satisfy all æsthetic requirements in interior decoration. In places where distemper is now used such a material would fulfil all the requirements, and would have the additional advantage that the surface could be readily cleaned and would not wear off. An asbestos-cement sheeting which dispensed with the services of the painter and paperhanger as well as the plasterer would have a still greater claim to consideration as a cheap building material.

DESIGN AND COLOUR TREATMENT IN CONCRETE.

By REGINALD HALLWARD.

Now that concrete is emerging from its industrial use into further fields of activity, and is being recognised as a material not only for cheap building but for purposes which include architectural beauty, the consideration of treatment as well as strength and durability becomes very important. To those who are inclined to regard concrete as a new material without the claims of timber, brick, or stone, it is as well to remind them that concrete is of very ancient ancestry. Precedent and tradition count so much in an old country that one may as well, for those who are troubled with prejudices against it on this account, point out that concrete was made of use in the Pyramids of Ancient Egypt, and that the Egyptians set the bricks (firebricks) on concrete in making the large incubators in which they raised their poultry. In presence of a hesitation to recognise this material as of traditional descent, one is reminded of a well-known cathedral city in which, so it is said, it is no use thinking of taking up one's residence unless one is able to prove the impeccable social claims of his great-grandfather! Seriously, need we trouble ourselves very much about all this, at a time when there is so much need of freeing our minds of the burden of use and wont and necessity to embrace the possibilities lying in new industrial and artistic resources? It may be recalled by those who would regard concrete as limited to the requirements of cheap construction that the new wing of the General Post Office is built of this material, not to mention other Government buildings. With all

A Country Cottage.
Design and Colour Treatment in Concrete.

these ancestral and other associations of so much respectability, may we not claim for concrete the same consideration as a building material as timber, brick, or stone? And if not, why not? We look for developments of great architectural significance as we gradually perfect its treatment, and apply it to the noblest ends.

The object here, however, is to consider certain aspects in the use of concrete other than utilitarian, and to call attention to the primary importance of working through the material, by which we mean that it should express its own qualities and not ape other materials. Attempts to disguise its nature, such as imitating the surface form of worked stone, rustication, or other treatment are likely to be detrimental to its own prerogatives and to hinder progress, because they darken knowledge of the qualities lying in its own nature.

In regard to colour treatment, the method of exposing the aggregate has realised some beautiful results, but when we have got both surface and colour the larger problem is the arrangement and use of these to the best advantage, and care needs to be taken lest we introduce one colour too expansively. The use of black and white (which means a grey black and white, as the contrast should never be over-emphasised) offers possibilities of endless variety for string-courses, chequer-work, windows and doors. We are familiar with the flint-and-stone courses in mediæval building, so delightful in effect, and a similar beauty and charm is derivable from concrete by using the opportunity which it presents for a like treatment. Ornament should, however, be used sparingly, not as sometimes in the past to give a meretricious value and cover up bad building, and when it grows out of a construction properly expressing the character of the building it is a delightful addition. A wide variety of colour is obtainable by the admixture of oxides, but some more responsible artistic direction is, we think, required in order to secure better results; a red, for instance, of more Venetian and brick-like colour than the purplish red we have seen, and with a surface more interpretative of the material.

In claiming for concrete its artistic adaptability, the responsibility which this entails must be borne in mind. While allowing full weight to considerations of cost, it must also be understood that where artistic excellence in design and proportion is claimed for the material it cannot be reached on wholly utilitarian lines. In roofing, for instance, the diagonal tile, though most economical to lay, is often unsatisfactory in size and lacks repose, and also in regard to the size of the tile, or the block, the right proportions are very important. Again, when we are governed by artistic considerations, there needs to be not only actual strength of construction, but the appearance of it, that it may convey that amplitude which we see in great architecture. The appeal is to the eye as well as to the mind. An example of this is a reinforced concrete bridge on the Great Western Railway between Ealing and Wood Green (illustrated in our frontispiece). Here the piers, or supporting columns, although no doubt of the necessary strength, appear to be a little weak in relation to the superstructure; the appeal to the eye requires that they should be slightly thicker in order to give a sense of ample supporting strength. We have the resources all about us for fine work, but we need the training to use them to the best ends, and the concrete industry will require its schools wherein the science and the technical and artistic needs can be fertilised and made of fullest account. In this way a sixth order of architecture—an architecture the direct expression of our own life and civilisation—will shape itself out of a material which as its possibilities develop reveals more and more its adaptability to this great and liberating end. If it will be itself—make its own path, not regardless of the past of construction and architecture, but adapting them to its own needs—it will produce a beauty of its own because it will grow out of itself.

The advantage—and it is a great one—of a new material with such great architectural possiblities as concrete, is that we are not loaded up with all the traditions and habits of use, style and treatment that influence brick and stone. Our landmarks are in front of us. We are not directly concerned with the five

A Country House.

Design and Colour Treatment in Concrete.

orders, but to make a sixth. Whereas everything is known in the case of other materials, the resources of concrete have yet to be further developed. Nor need we hunt up precedents before doing a thing, but make our own. How agreeable it is to think of ornament which is no longer the hereditary accompaniment, but something vital and evoked out of the material, incorporating our own sense of beauty and fitness. How encouraging to feel this new dawn of youth, the world of building once more at the beginning, the burden of the past lifted from its shoulders, free to develop itself, to make its own house of life, and front the world anew!

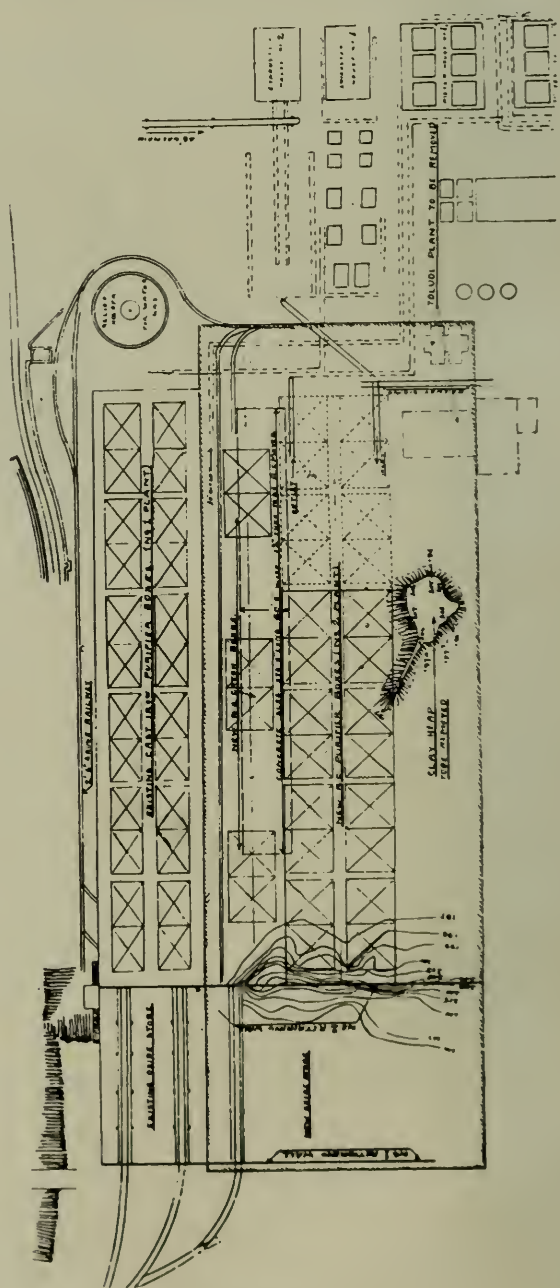
REINFORCED CONCRETE GASWORKS PLANT.

By B. N. DEY, B.Sc., A.M.Inst.C.E.

THE adoption of reinforced concrete in the construction of industrial plants is now almost universal. This material received a great impetus from the demands created during the war, when steel for structural use was practically unobtainable except for war requirements. Its increasing application in buildings, bridges, bunkers, tanks, foundations, and industrial structures was extended to water and oil-tight structures (as in concrete ships, dock gates, etc.), and to gas-tight tanks known as purifiers in gasworks. Long after its invasion into other parts of gasworks its importance and usefulness as a strong, durable, and economical material for the construction of gas-tight purifier tanks were recognised by gas engineers, who were interested in the facts that these tanks could be built at a far lower cost than those in cast iron, and would require no upkeep, not being affected by the gases and vapours in a gasworks which have a corrosive action on iron and steel.

The Corporation of the City of Glasgow has in course of completion at Provan Gasworks what will be one of the largest and most modern purifier installations in this country. The plans, schemes and designs for this extensive plant were prepared by the author, who provided as far as possible for the use of concrete in various forms, both plain and reinforced, on the " Economic " system of construction. The concrete works comprise foundations and bases for valves and machinery, floors at different levels carrying railways, retaining walls, overhead tanks, buildings, piers and girders supporting standard-gauge railways, platforms and gangways, and various structures supporting large diameter pipes, runways for lifting gear, conveyors, stairs, roofs, etc.

The plant is to be used for purifying large volumes of gas. The gas, as manufactured from coal by heating it in closed retorts, is full of impurities, of which tarry vapour, ammonia, etc., are removed by cooling and washing, and the remaining impurity—sulphuretted hydrogen—is eradicated by passing the gas through layers of hydrated ferric oxide (found in natural state as " bog ore ") placed in large tanks or purifier boxes, each having four steel covers with rubber lutes and fixings. The boxes are carried on columns and beams about 13 ft. from ground level. Periodically, the spent oxide is removed from the boxes by discharging through the holes in the floor of the boxes into bogies run on rails below the purifiers. Fresh or revived



SITE PLAN.

PROVAN GASWORKS:
Works under Construction: Retaining Wall No. 2 on Left.

oxide is to be supplied from the revivifying floor about 9 ft. above the boxes, through discharge shoots or conveyors. The oxide is to be brought and distributed over the revivifying floor by a 2 ft. 6 in. gauge railway from the oxide store at the west end, which in turn is replenished from the 4 ft. 8½ in. gauge rail tracks at a higher level delivering both fresh and spent oxide, through disintegrators, into the narrow-gauge bogies underneath. The mains supplying the gas to the plant are 48 in. diameter, reducing to 30 in. at the west end. The connections from the mains to the purifiers are 24 in. diameter, and 18 in. diameter pipes, with various valves. The oxide is placed on wooden grids resting on steel bearers supported on concrete ledges and brackets inside the boxes. The steel covers are lifted when required by lifting gear running on runway joists fixed to beams under the revivifying floor.

The area of ground within which the new plant is being erected is about 702 ft. from west to east and about 240 ft. from north to south, amounting to about 19,000 sq. yds. The new plant is laid out to deal with 24 million cu. ft. of gas per day, comprising twenty-four purifier boxes with six catch-boxes (erected between the existing plant and the new purifier plant) which will be used in case of failure of the routine sets of either plant to do the work of purification. The building containing the purifier boxes when completed will be 505 ft. long from the face of No. 2 retaining wall. A revivifying floor is constructed within this building at a height of about 32 ft. from the ground. At the same level on the high ground between Nos. 1 and 2 retaining walls, the new oxide store, about 150 ft. wide, is laid out. Stairs with access to different levels are provided at different points in the plant. Approximately 80,000 sq. ft. of roof area is covered by corrugated asbestos sheeting, with ventilators and gutters for adequate roof drainage, etc. The roofs are carried by steel roof trusses supported by reinforced concrete eaves and valley beams and columns.

DESIGN.

Probably no other system of construction requires so much thorough knowledge of the theory of structures and of the properties and strength of materials used as concrete ideally reinforced with steel. Although limitations in stresses of concrete and steel were imposed, the author was allowed to use the methods embodied in the "Economic" system developed by the author in the preparation of his designs and instructions for the contractors. These methods are at variance with many established ideas based on designing always in analogy with similar steel structures. Practical considerations also governed the design. The scantlings of the different members of the structures were determined by economical practice, enabling removable units of shuttering to be used repeatedly. The reinforcements were arranged so that they could be easily placed and inspected.

One of the main features of the design is the comparatively thick slab with few ribs, which has proved to be economical, simple, and easy for erection, amply strong to withstand all stresses, and more effectively waterproof and gastight than thin slabs with numerous ribs. Past experience has also proved that oil and gas-tight tanks should first be properly designed with sufficient reinforcement (meshwork on both faces as far as possible) to resist every stress likely to be encountered, and that the concrete be properly proportioned (a mixture of, say, cement, 1 ; sand, 1½ ; aggregate, 3), mixed, placed, and adequately protected during early hardening so as to develop the proper strength and density ; unless these two essentials are taken into consideration, no coating on the inside will compensate for them.

PURIFIERS AND CATCH-BOXES.

These boxes are grouped in pairs. The unit pair consists of two boxes with a partition wall between them, each box having an inside measurement of about 1,550 sq. ft. area and at least 6 ft. depth. The floor slab is an average of 8 in. thick, divided into panels about 20 ft. square, which are bounded on three sides by beams 12 in. by 30 in. deep (overall), and the wall beam on the fourth side, carried on columns, one at each corner of the floor slab panel. The wall slab forming the sides of the boxes is 6 in. thick, and is reinforced to resist lateral pressure due to both pneumatic and water tests. It is also designed to act with the bottom beam portion (9 in. by 30 in. deep) forming a wall beam to support one side of the floor slab. The junctions of the wall slab with the floor slab at the bottom and gangway slab at the top are adequately reinforced to resist end fixing moments. The roof of each box is formed by 12 in. thick gangway slabs, leaving four square openings, each about 15 ft. by 14 ft., covered by steel covers. The side gangways are 3 ft. wide. The two centre gangways at right angles to each other are 5 ft. 6 in. wide, and are tied to the floor slab and supported by a central and four other pillars.

The floor and side (wall) slabs are designed to sustain the hydraulic test of filling each box brimming full of water, and to withstand all stresses due to a 4 ft. depth of oxide (65 lb. per sq. ft.), evenly distributed, and localised loads due to inlet and outlet pipes and oxide discharge valves. The floor, sides, and roof (gangways and covers) are also designed to sustain the pneumatic test of 50 in. water-gauge pressure applied for six hours. The gangways are designed also to carry an external super-load of 56 lb. per sq. ft. direct and transmitted through the covers, over and above the weight of the covers. The inside pillars are designed to carry loads transmitted by grid bearers (supporting grids carrying oxide) and to withstand all stresses due to a pneumatic test of 50 in. water-gauge pressure. The beams are designed to carry the distributed load transmitted by the floor slab and to withstand all stresses due to localised loads from the pillars inside the box, and from gas pipes carried on slings supported from the beams below the floor slab. The beams are designed not to deflect more than one-thousandth part of their span under maximum loading.

The floor in each box is laid to fall to four drainage holes, and is also provided with eight other holes 18 in. in diameter, four for emptying oxide, two for inlet, and two for outlet gas pipes. Reinforced concrete ledges and brackets are provided along the side walls to carry grid bearers. The gangway is built with lugs in proper positions for covers and fixtures to carry a steam coil. The floor, sides and gangways are reinforced with steel bars in two directions at right angles to each other. The concrete mixture for the boxes (floor, sides, gangways, beams) is 1 : 1½ : 3, and for columns is 1 : 1 : 2, representing the proportions of cement, sand, and aggregate.

REVIVIFYING FLOOR.

This floor over the whole area of the purifier house above the purifier boxes is designed to carry a load of oxide 4 ft. deep, or 260 lb. per sq. ft. The floor slab is an average of 8 in. thick, divided into panels approximately 19 ft. by 20 ft., and 20 ft. by 21 ft., bounded on each side by a beam 12 in. by 25 in. deep (overall). The floor is finished smooth on the face by ¾ in. granolithic incorporated into the slab. One hole in the centre of each panel is provided for distributing oxide to the purifier below. Drainage holes and holes for hydrants and sinks (water supply) are also provided. The floor is graded to surface drains. Each panel is designed for maximum bending moments at the centre and at the supports, due to the

PROVAN GASWORKS:
Part View of underside of Purifier Boxes, showing Spacing of Beams and the large Panels of Slabs.

most severe cases of loading, viz., maximum for centre when alternate panels are loaded, maximum over support when adjacent panels are loaded. The floor slab is reinforced with steel bars in two directions at right angles to each other, both top and bottom. The reinforcements at the top face are provided to take up tension from induced bending moment due to loading of an adjacent panel and part compression due to centre bending moment when the panel itself is loaded.

The retaining wall around the revivifying floor is 6 in. thick and 6 ft. 6 in. high, and is designed to retain oxide heaped against it up to 6 ft. deep. It is also designed to act with the bottom beam portion (9 in. by 25 in. deep) forming a wall beam to support the end floor panels. The junction of this retaining wall with the floor slab is adequately reinforced to resist end fixing moment. The reinforcements provided in the wall are steel bars in two directions at right angles to each other and on both faces. Openings are provided in this wall for conveyors and for staircase landings where they occur.

The beams are designed to carry the distributed load transmitted by floor slabs, loading due to a 2 ft. 6 in. gauge railway laid on the floor, and loading due to runways (supported from the beams under the floor) carrying travelling lifting gear with raised covers. The concrete mixture for the floor slab, beams, and retaining wall is 1 : 2 : 4, and for the columns supporting the floor is 1 : 1 : 2.

OXIDE STORE.

The railway track girders are designed to carry a working load of 2 tons per lineal foot, and are supported on mass concrete piers, the end supports being the No. 1 retaining wall at one end, and two reinforced concrete columns transmitting the load through a girder to No. 2 retaining wall at the other end. Over each support is provided a cantilever designed to carry columns supporting the roof. A gangway 3 ft. wide is provided along each track girder, and is designed to carry a superload of 56 lb. per sq. ft. Two platform slabs, each 12 ft. by 25 ft., carry the disintegrator machinery and motor house, and are supported by reinforced concrete beams and columns.

All roof trusses and roofing are carried by reinforced concrete eaves and valley beams supported by reinforced concrete columns. All columns are designed for both direct load and induced bending due to beams fixed to the columns, with which they are monolithic. The combined direct and bending stress per sq. in. in every case does not exceed that allowed for the direct stress alone. All beams are designed for maximum bending moments at centre (when alternate spans loaded) and maximum bending moment at supports (when adjacent spans loaded), taking into account the fixity with columns. Triangular distribution of load has been assumed as being transmitted by the floor slab to the supporting beams, which are accordingly designed. Wind pressure as specified by the L.C.C. Regulations is taken into account in the designing of all structures.

The floor slab forming the ground floor under the purifiers and catch-boxes is made of mass concrete varying from 6 in. to 4 in. thickness, laid to drain falls; 2 ft. 6 in. rail tracks are embedded in them and drained. The various valves and other foundations are of mass concrete. The oxide store floor is made of 1 : 3 : 6 mixture of concrete, average 4 in. thick, reinforced with ⅝ of 1 per cent. of steel and graded to surface drains.

Sharp bends and small angles with verticals are strictly avoided in all reinforcements, specially those diagonal bars provided for shear. The shear reinforcements mainly consist of one set of diagonal bars from point of contraflexure at the bottom of the beam to the column support at the top of the beam, instead of the common practice of providing many sets of diagonals with sharp bends at intervals. Stirrups are also provided to take up shear in beams. Columns are adequately hooped.

CONSTRUCTION OPERATIONS.

It would be interesting to give a concise account of the methods employed in the various construction operations and the results obtained in the endeavour to attain the maximum output and speed of erection compatible with first-class work being ensured, and practicable under existing circumstances influenced by local conditions. The present-day system of organisation and scientific management applicable to the erection of straightforward structures on open sites had to be considerably modified to suit a complex scheme with reinforced concrete and steel structures, elaborate drainage, intricate pipe-lines for gas, steam, and water valves, lifting gears, conveyors, and railways at different levels, all involved with one another and contiguous to existing plant.

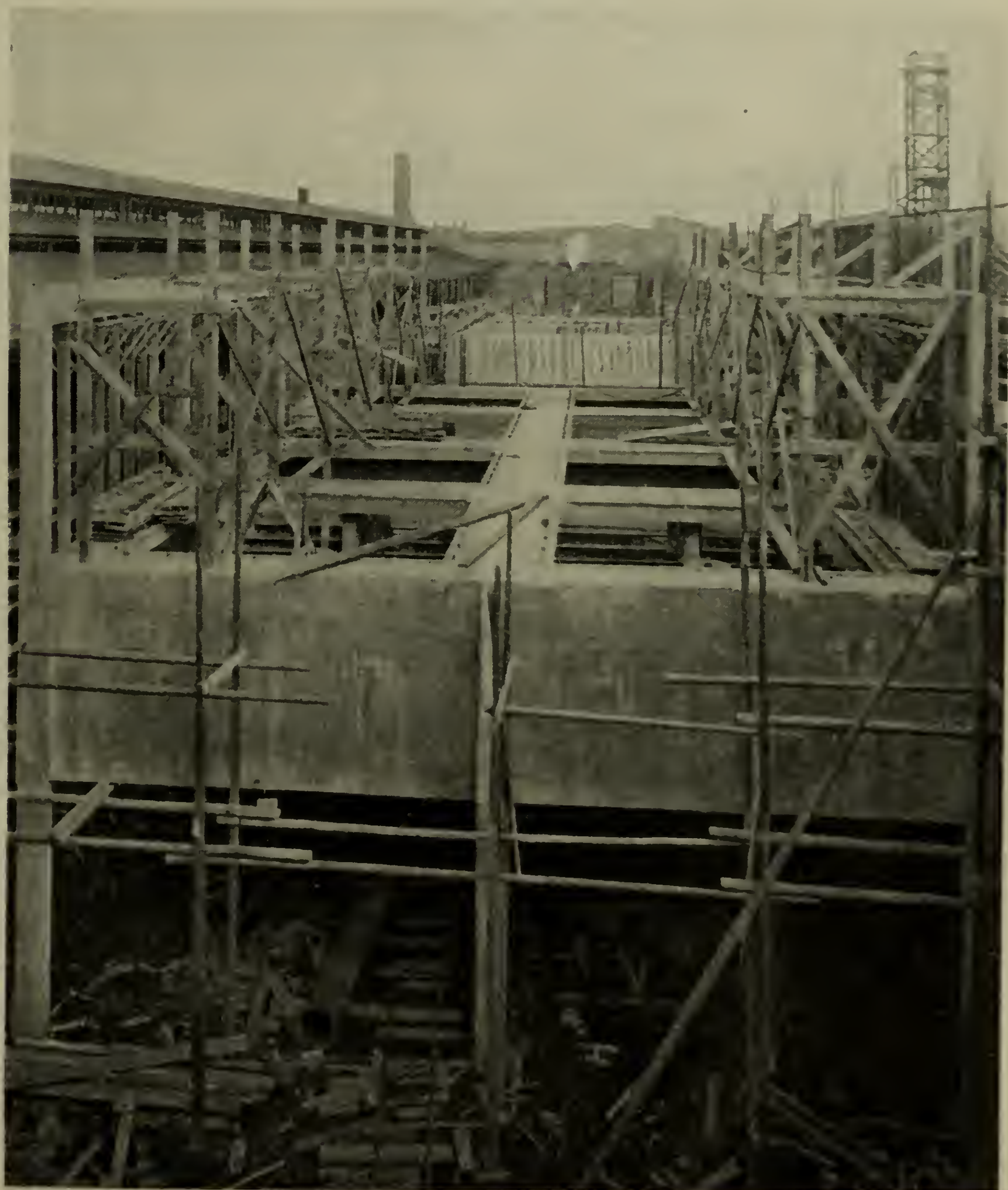
The progress of the works, started nominally in May, 1921, was hampered by the coal strike until August, 1921, when the first consignment of column reinforcements arrived, enabling the operations to be started in full swing. By the end of the year nearly a third of the work was completed. In spite of the suspension of operations for two weeks at a time due to frost, a steady progress on the average was maintained, resulting in over two-thirds of the works being finished by the end of March, 1922, and the remainder well on the way towards completion. It is anticipated that at this rate the whole works will be finished by August, 1922, which if fulfilled will probably establish a record in industrial construction in this country.

SITE, NATURE OF GROUND, EXCAVATION.

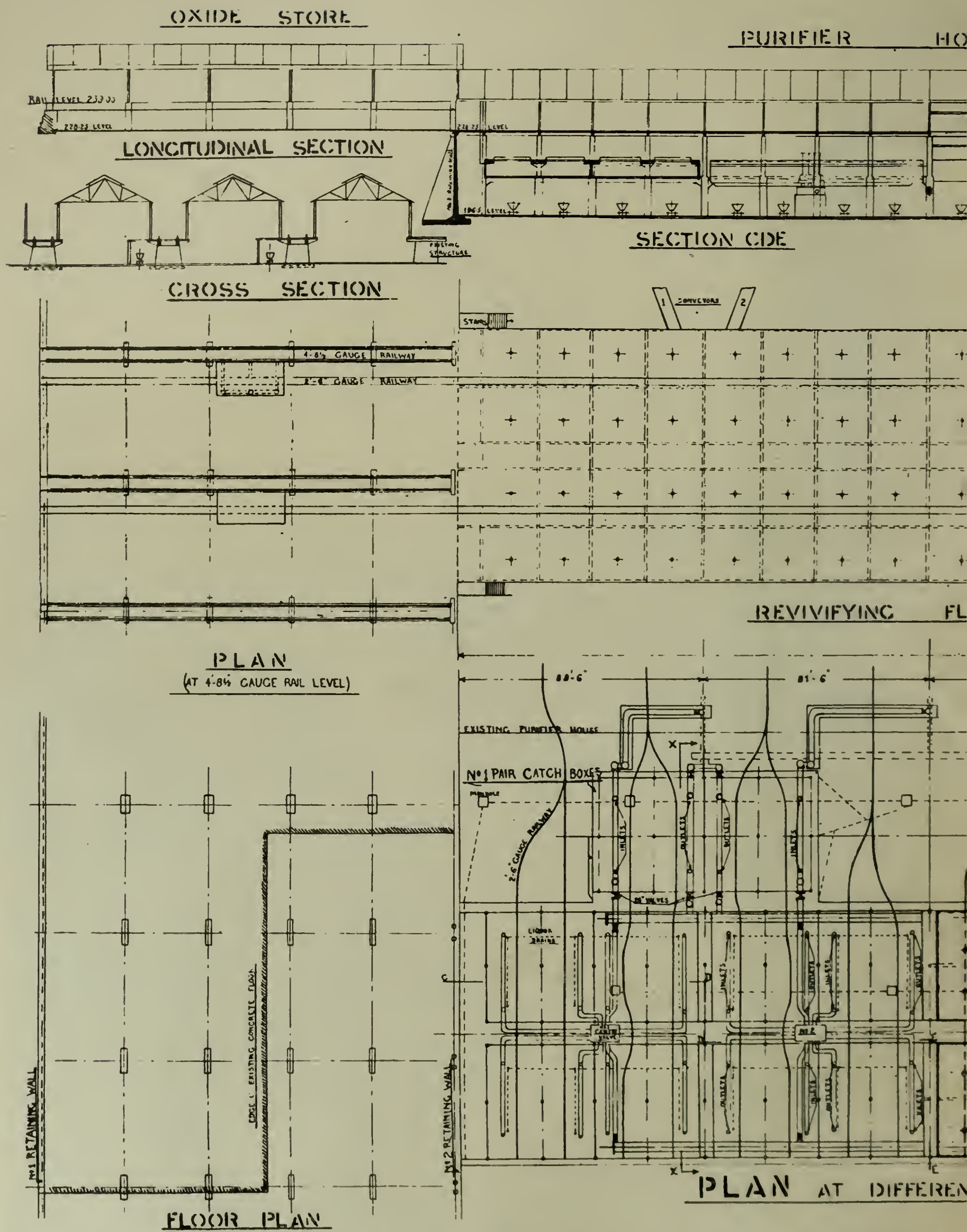
It was decided to proceed first with the construction of a reinforced concrete retaining wall (35 ft. high and about 200 ft. long) on a line denoting the division between the oxide store at the high level and the purifier house and other plants at the low level. From the contour plan it will be seen that the foundation of this wall had to be excavated near the toe of a sloping embankment, a considerable portion of this slope being on the area to be covered by the purifier house. This excavation had to be done and the spoil removed so as not to interfere with the two sets of purifier boxes (adjacent to the wall) required by the Corporation to be completed as soon as possible. Difficulty was experienced in obtaining adequate area on the oxide-store floor level to accommodate sufficient spoil from the wall, area, and column foundations excavations necessary for infilling behind the wall without placing too great a surcharge on the upper level to the vertical face excavation required in the bank to provide the requisite width of foundation for the wall.

The excavation for the wall was commenced at the south end, the spoil being hoisted to 228·25 level by means of a 5-ton steam derrick crane mounted on travelling bogies placed parallel to and distant 5 ft. from the top edge of the slope of the bank. This arrangement allowed the use of a 75 ft. jib. The area, "clay heap," and column foundation excavation was commenced from the east end of the site, and the spoil conveyed in narrow-gauge train loads to within reach of the steam crane for hoisting and depositing on the upper level, to be used for infilling later on. This crane travelled towards the north and formed spoil banks.

The nature of the ground generally proved to be boulder clay, necessitating the use of explosives for wall and "clay heap" excavations. The column foundations, being carried to no considerable depths, were executed with ordinary pick-and-shovel methods. Towards the end of the wall excavation progress was made in this work by directing streams of water from hose-pipes to thin horizontal beds of sand found at intervals, allowing undercutting of the boulder clay above and proving a desirable combination when using explosives. Explosives used were 50 per cent. nitroglycerine composition charges fired by time-fuses; gunpowder had not even a loosening effect, merely forming "pot" holes. Such being the nature of the

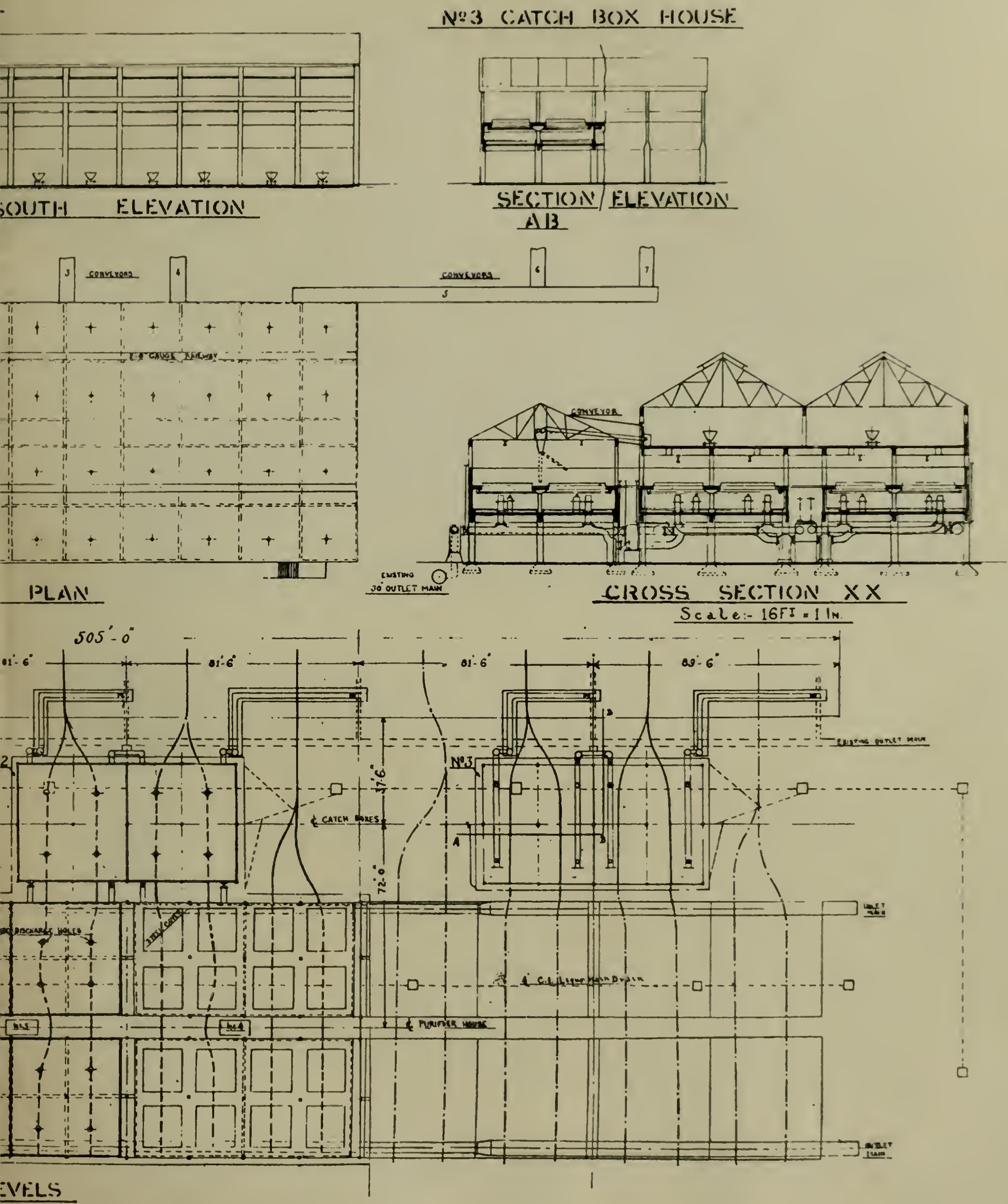


Provan Gasworks:
Pair of Catch-boxes in course of Erection (up to Gangway Level).



PROVAN GASWO

The words "Inlet Main" and "Outlet Main" on the right o



PURIFIERS (*see pp.* 334 *and* 335).

awing should be transposed: the Outlet Main is the upper one.

ground, an elaborate method of timbering (piles, walings, sheeting) the vertical face excavation for the wall was not necessary. The method used was that of raking shores through the line of the wall, each requiring to be removed as work reached the point of intersection with them and being replaced with further temporary struts to the walings from the back splay of the wall at the base. The excavations for drains and other pipe trenches were executed in the ordinary way.

CONSTRUCTION PLANT, ETC.

The nature of the available site and the disposition of the existing works did not permit of many facilities for carrying out the construction works. The lay-out of the mechanical and other plants required for construction operations and the temporary buildings and sheds was accordingly schemed to the best advantage to suit the site. It was decided to install electrically-driven plant in order to eliminate any possible risk of gas explosions owing to the field of operation being so close to existing gasworks. Connections were obtained at a new substation of the Corporation located within the gasworks. This entailed the erection of over 1,300 lineal yards of cables suitable for a series of motors totalling 60 horse power, wound for 440 volt 25 cycle 3-phase alternating current. A motor-driven 30 in. diameter circular saw was installed to expedite the preparation of the shuttering. The plant for preparing steel reinforcements consisted of two manually-operated benders, and these proved capable of an output sufficient to cope with concrete placing requirements.

Temporary buildings consisted of riggers' shed, joiners' tool-store, foremen's office, joiners' workshop, cement receiving shed, general store, steel preparing shed, pipe fitters' workshop, labourers' bothy, etc. Materials were generally railway conveyed, standard-gauge sidings being situated on the south and east sides of the site, an area adjoining each being reserved for unloading heavy pipe connections, valves and other castings, rails, and steelwork.

MIXING AND PLACING OF CONCRETE.

Concrete was mixed by means of two "Ransome" self-elevating feed-hopper type mixers, each of $\frac{1}{3}$ cu. yd. capacity, and another mixer placed on 196·50 level near the retaining wall and later in the purifier house. Cement was stored and aerated in bins of 10 tons capacity, placed immediately behind the mixers, the requisite quantity for each batch being measured into boxes, and as required the contents of these boxes were weighed. Hoisting of concrete was by means of two timber hoist towers, each 72 ft. high, equipped with "Ransome" type automatic tipping-hoist bucket having a hoisting speed of 70 ft. per minute from a belt-driven friction winch situated at bottom of the towers; the concrete was discharged into receiving hoppers and conveyed by metal chutes to receiving platforms placed within short wheeling distance of "points of fill." The actual placing was done from barrows depositing their contents where required, attention being rigidly given to ramming and punning around reinforcements. These methods ensured that at such points as at the junction of the reinforcing steel from four beams over a column the supply of concrete could be diminished in order to allow proper ramming to surround all the steel reinforcements, whereas if these points were filled with concrete direct from the chutes the quantity may be overwhelming to the operatives, with the result that particles of the aggregate may lodge between the upper bars and prevent proper surrounding of lower bars with concrete.

For the construction of the retaining wall one mixer was placed at 196·50 level near the centre of the wall to allow of filling the base and bottom-splay concrete direct from narrow-gauge travelling side-tip wagons running parallel to the face of the wall. The upper portions of the wall were filled by hoisting skip wagons to 228·25 level and discharging their contents to timber chutes placed on the slope of the bank, concrete being collected on receiving platforms placed between counter-forts. In addition to the cement storage close to the mixers, a cement receiving shed was constructed centrally between the mixers capable of holding a sufficient quantity to permit of twenty-eight days' test before using.

The quantity of measured placed concrete in one week of forty-nine and a half hours amounted to 200 cu. yds., this work being to requisite thicknesses, a large proportion of which (in floor

Provan Gasworks :
Part of Revivifying Floor.

slabs) necessitated screeding off to depth gauges and subsequent tooling to provide the desired finish.

MATERIALS TESTS.

Concrete aggregate consisted of basic steel slag crushed to pass a ¾ in. mesh. Sand from local pit supplies proved to bulk well with aggregate. Results from crushing tests on 6 in. cubes at twenty-eight days taken from batches of 1 : 1½ : 3 mixture in course of depositing showed 3,300 lb. per sq. in. The cement used consisted entirely of Portland cement of medium setting standard. No water-proofing compositions were added to the concrete.

SHUTTERING.

Throughout the work the shuttering used consisted of 1⅛ in. thick white pine butt-edge jointed boarding, machine dressed on both faces and edges. For slabs, the decking was laid on 6 in. by 3 in. joists supported by runners and struts wedged upon timber soles well embedded in the ground. For vertical boarding the shuttering was supported by 6 in. by 2 in. profiles placed on edge and fixed above the concrete gangway level by runners to inner profiles, which were again racked between themselves to form a rigid structure ; no bolts were placed from outer to inner shuttering through walls which were later to be subjected to water and gas-tight tests. Shuttering for beam soles was constructed in timber 3 in. thick, which allowed of the use of fewer struts—a considerable advantage in providing working space for handling large diameter gas-pipe connections. Ample provision was made for washing out all beam forms and wall boardings by means of large-size apertures. It was considered advisable to leave the decking of the slabs for a period of three weeks after concreting before striking ; vertical boarding was struck four days after concreting, and beam soles were allowed to remain with all supports in position for six weeks before striking. The various castings (e.g., outlet and inlet pipes, oxide discharge valves) embedded in the floors were supported independently of floor shuttering ; these supports were allowed

CATCH BOXES AND ADJACENT PURIFIER HOUSE UNDER CONSTRUCTION.

to remain in position for some time after striking the slab shuttering. Great care was taken to have all seams and interstices in the shuttering closed before commencing concreting, with the result that large areas of the work required no further treatment to give a satisfactory skin finish.

The detailed information respecting construction operations on the site was supplied by the Contractor's Resident Engineer in charge. The main contractors are Messrs. Gray's Ferro Concrete Co., of 156 St. Vincent Street, Glasgow, and 12 Norfolk Street, W.C., who are carrying out the works to designs, drawings and detailed instructions issued by the author from his London Office, and under direct supervision of the author's Assistant Engineer at Glasgow.

PART OF REVIVIFYING FLOOR, SHOWING MESH REINFORCEMENT.

MILD *V.* HIGH-TENSION STEEL FOR REINFORCED CONCRETE WORK.

By W. L. SCOTT, A.M.Inst.C.E.

A GREAT deal is being written at the present time by the advocates of high-tension steel respecting the advantages this material is supposed to possess over ordinary mild steel of the usual specification when used as reinforcement in concrete. From this it would appear that mild steel reinforcement of a plain round section possesses probably almost all the faults that it could modestly contain, while high-tension material is presented as being almost angelic in its virtues and in its sympathetic action with the adjacent concrete under any condition.

An examination of the respective qualities of the two steels under working conditions, however, shows that any advantage contained in the more expensive steel only becomes material at stresses beyond the elastic limit of ordinary mild steel. When this condition for the tensile reinforcement obtains any comparison of the two types of bar becomes futile, as the member or structure in question has ceased to be of any practical use, due to the deflections caused by the excessive loading necessary to produce this stress.

It will be noted that no claim has been made for high-tension reinforcement where the tensile stress is kept within the limits permitted by the present regulations of the various governing authorities, nor is it definitely claimed that this particular material can withstand a higher stress elastically than mild steel without a similar disruption of the surrounding concrete. The latter fallacy, however, is often inferred, and the reader is asked to reason that an addition in the elastic limiting value justifies a proportionate increase in the permissible working stress.

The latter assumption is entirely wrong, for the following reason: The modulus of elasticity of mild steel, mechanically-treated steel, and structural carbon steel remains very nearly constant, and consequently any elastic stress sufficient to crack the concrete in one type will crack the concrete surrounding any of the others, and to exactly the same extent. Insufficient recognition appears to have been given to this fact in the cases where a higher stress for the material has been adopted for reinforced concrete building and engineering work generally, though it is interesting to note that several years ago Lloyds' Register of Shipping refused to allow any increased working stress to be used for high-tension reinforcement where this material was employed in the construction of the reinforced vessels being classed with the Register at that time, both in this country and abroad.

It must be borne in mind when talking of working stresses that the figure of 16,000 lb. per sq. in. for mild steel is not necessarily the stress actually imposed upon the tension reinforcement, but merely an arbitrary figure used for calculation purposes. For instance, when it is estimated on paper that there is 14,500 lb. per sq. in. on the tension steel, it has been proved by actual test that the true stress in the rods may be something over 9,000 lb. per sq. in. and under 10,000 lb. per sq. in. This difference, of course, is principally due to the assistance given to the tension reinforcement by the concrete surrounding it.

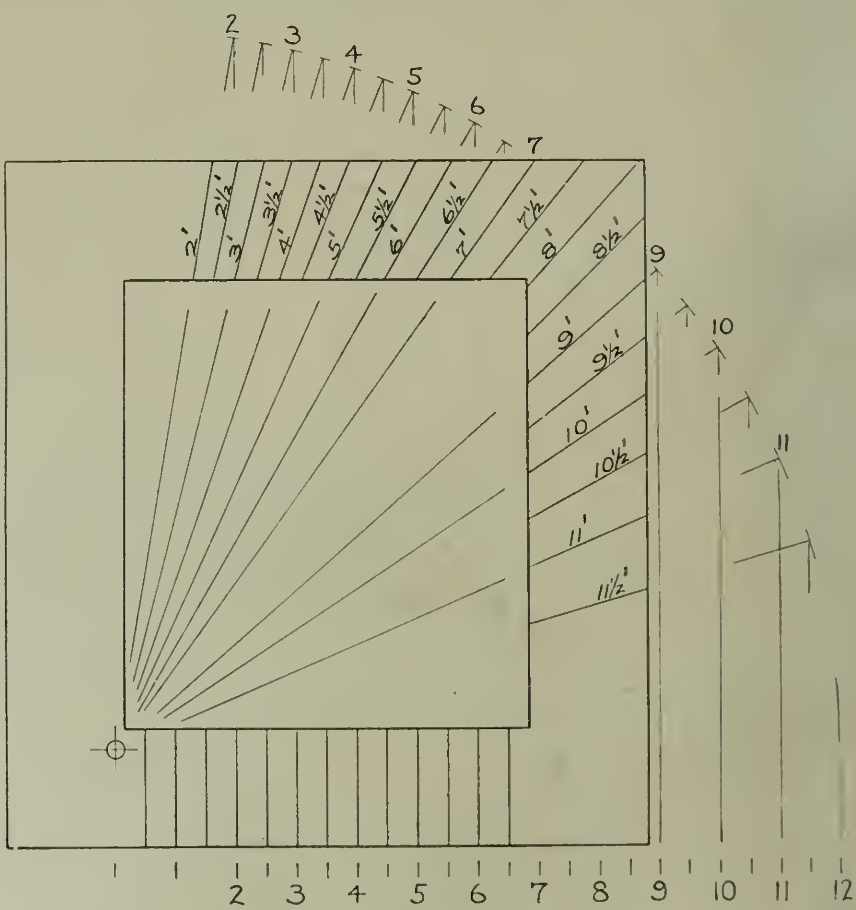
Whilst the writer was in the United States some ingenious tests were carried out by the American Shipping Board in connection with the construction of their reinforced concrete vessels to ascertain this fact, and from the results it was decided to limit the design stress to 6½ tons for these craft, this being the highest to ensure absolute immunity against hair cracks. These cracks, it may be interesting to state, may be detected by ear, through a microphone, some considerable time before they first become apparent to the eye.

It is only fair to the users of mild steel reinforcement to emphasise the above facts, and to focus attention upon the true features governing the respective values of this steel and the various types of high-tension rods produced by chemical and mechanical treatment. All the latter family of rods are directly comparable with those of ordinary mild steel at all stages of elastic stress, and any artificial raising of the elastic limit and ultimate strength merely provides "an extra margin of safety" against a condition never likely to be realised, or even approached in practical construction. To the very great number of distorted sections now on the market a similar criticism might be applied, since the respective adhesive values of ordinary mild steel rods are never reached in good practice, and any extra expense to secure a surplus adhesion would be much better devoted to increasing the diameter and providing a greater sectional area, thereby reducing the tensional stress and at the same time increasing the surface area available for adhesion between the concrete and steel.

SPACING OF REINFORCING BARS IN CONCRETE SLABS.

Mr. W. A. Green, designing engineer of the Trussed Concrete Steel Co., Ltd., London, has sent us the following notes and diagram :—It is sometimes necessary to set out on a drawing reinforcement spaced at regular intervals. The illustration shows a device which has proved useful. It consists of a frame constructed of thin celluloid which is laid on the drawing with the bottom edge at right angles to the reinforcing bars.

If a scale is placed so as to pass through the point O and lie along the inclined line marked with the required spacing of the bar centres, the foot marks on the scale will show on the drawing the position of the centres of the reinforcing bars, and if the unit mark on the scale coincides with the position of the first bar the number of bars can be read from the scale without calculation.



The lines drawn outside the frame in the illustration will help to make clear the simple construction for drawing the inclined lines; e.g., the inclined line for 5 in. centres is drawn by joining O with the point of intersection of a vertical line 5 units from O and a circle of 12 units radius with its centre at O.

The device can, of course, be used for drawings made to any scale.

If the frame is made in thin cardboard the point O should be at the intersection of the inner lines of the frame at the bottom left-hand corner, but in the deviser's experience an opaque frame usually hides the portion of the drawing one wishes particularly to see.

AMERICAN DOMESTIC ARCHITECTURE.

HOUSE AT MANCHESTER.

AMERICAN architects are fortunate in the assistance afforded in their composition by the addition of the loggia. The climatic conditions throughout most of the continent are such that the introduction of this feature is nearly always desirable, and the additional scope in design and treatment which its presence gives is very considerable. We have seen the loggia treated as a central figure, as a pavilion, as an integral part of the design, or added as a subsidiary mass. But wherever it is placed, by reason of its dark shadows and the mystery suggested by its deep recesses, it becomes a feature of interest.

At the first glance the design illustrated this month seems to have about it the picturesqueness of confusion, but a closer examination will show a clever balance obtained without resorting to rigid symmetry. Thus, gable balances

HOUSE AT MANCHESTER, MASS.

[*Mr. Arthur Huen, Architect.*

gable, yet they differ in detail. Great prominence is given to the loggias on the first floor, but these again are not exact replicas of each other, and the circular tower placed in the angle formed between one wing and the main building completes the somewhat mediæval suggestion which is characteristic of the whole design.

This building is executed in concrete, the method of construction being a framing of timber covered with expanded metal lathing to which the concrete is applied. The structural significance of the timber is clearly visible in various details of the design. That the building is not of quite recent date is apparent from the garden, which shows ample signs of maturity. It is interesting, therefore, to note that this system of construction has been in use in America for some time, while in England its simplicity and efficiency is only just being realised.

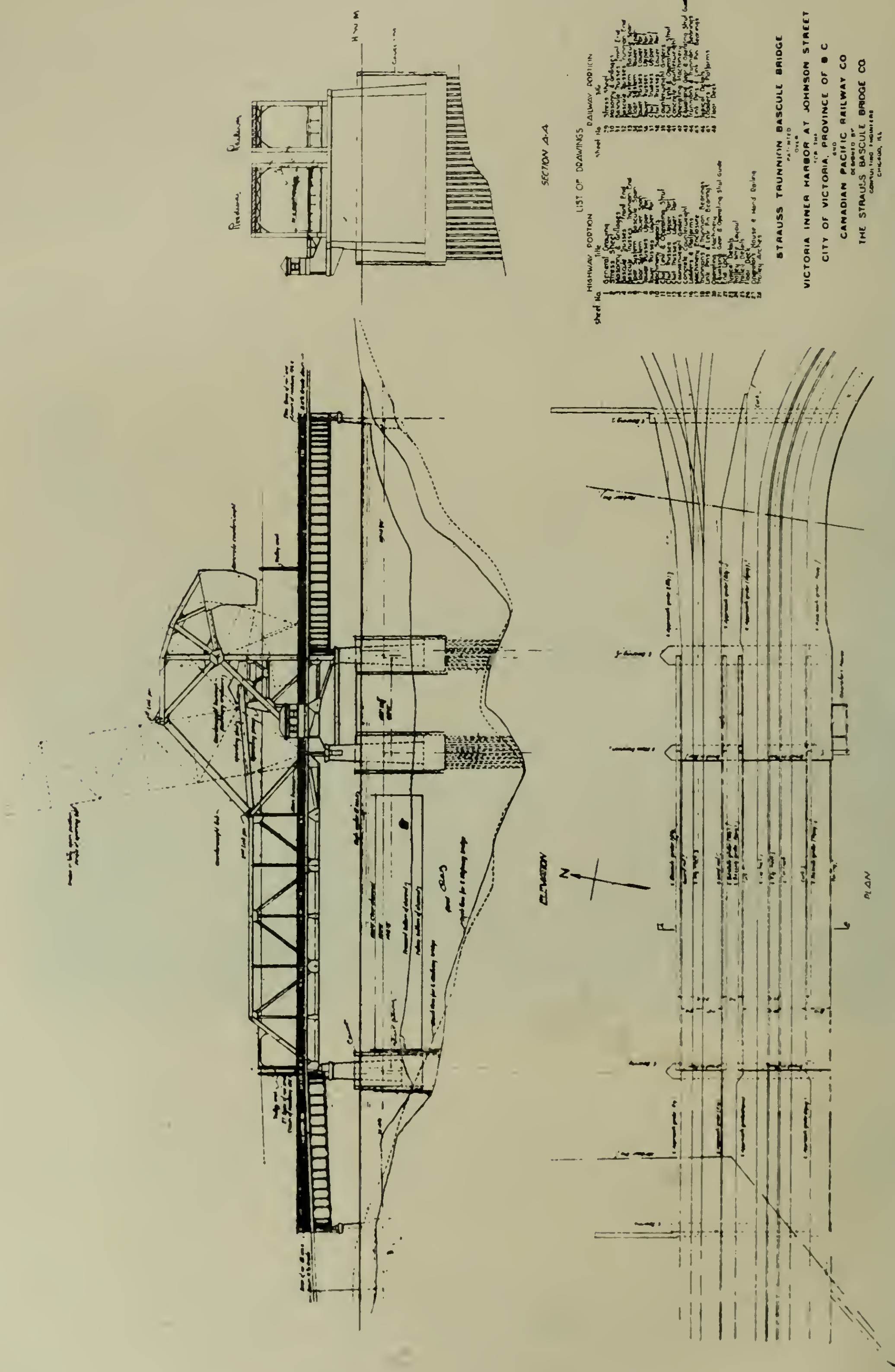


Fig. 1. Johnson Street Bridge, Victoria, B.C. (see p. 311).

CONCRETE IN BRIDGE SUBSTRUCTURES.

The Johnson Street Bridge, Victoria, B.C., is a combined railway and highway bridge across the inner harbour, built by the City of Victoria with the help of contributions from the Canadian Pacific Railway Company and the Provincial Government, at an approximate cost of 800,000 dollars. It consists of two independent "Strauss" bascule spans with plate girder approaches, constructed side by side, one for use as a roadway and the other for railway traffic, upon a common substructure. This design was necessary owing to the close proximity of the existing railway swing span, and so that both the railway traffic on the old bridge and the harbour traffic should not be interfered with. The bascules were

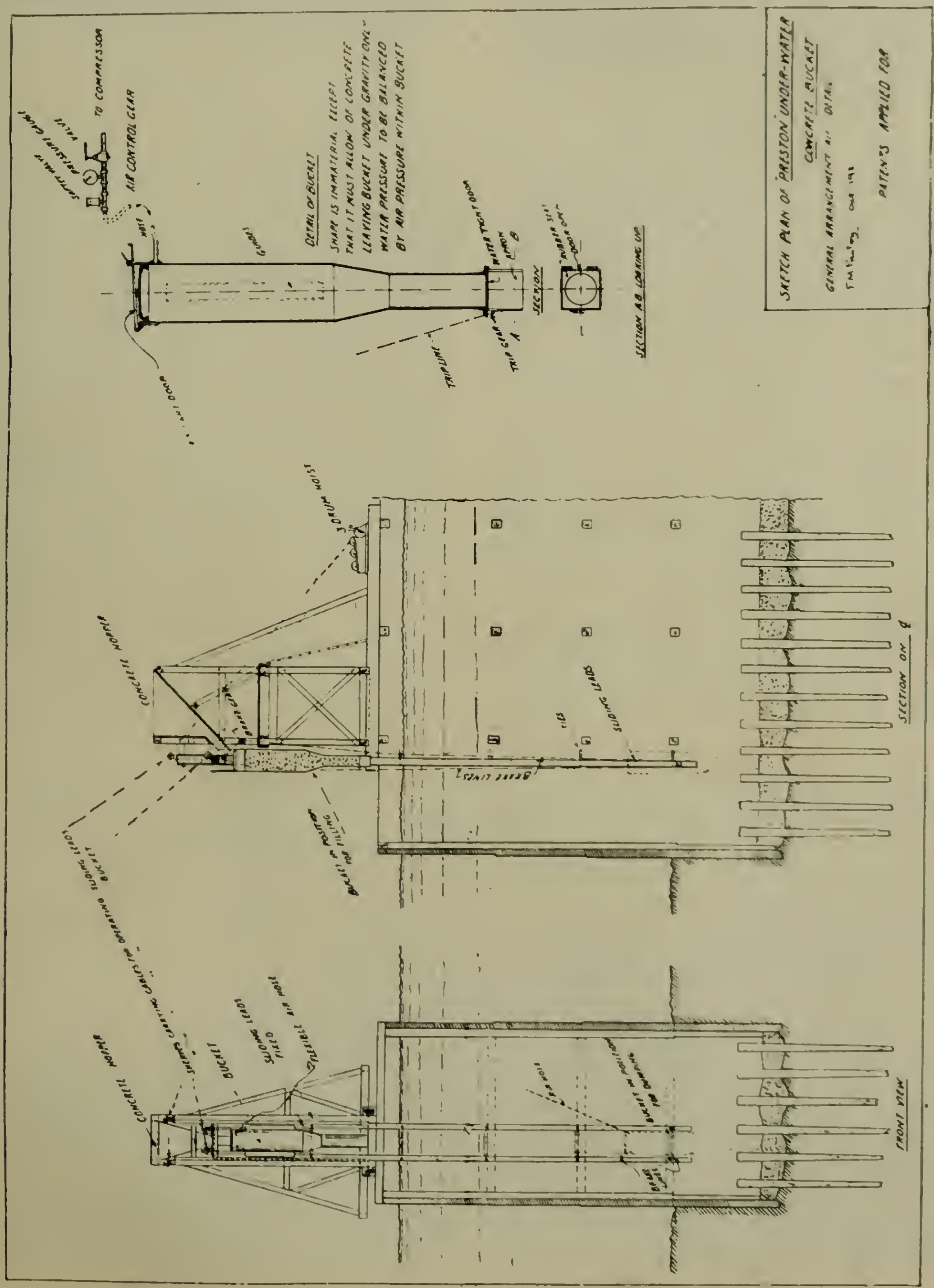


Fig. 2.

designed by the Strauss Bascule Bridge Company, and the rest of the work by the department of the City Engineer (Mr. F. M. Preston).

The substructure is now nearly completed, and the highway portion of the bridge is being erected by the Canadian Bridge Company. The substructure consists of concrete piers and abutments, and the work was carried out departmentally by the City Engineer at an approximate cost of 207,000 dollars, this cost being 28,000 dollars below the lowest tender received when bids were originally called for.

Fig. 1 gives a general idea of the lay-out. There are approximately 7,800 cu. yds. of concrete in the substructure. The abutments are of gravity section carried down to rock, and where the foundation work was below high water the work was kept dry by means of coffer-dams. Two of the piers, namely, the main trunnion pier (carrying the moving leaf) and the counterweight trunnion pier, are founded on piles driven through a clay subsoil to rock, and the third (or rest) pier is founded entirely upon rock.

The open dredging method was used, timber caissons being constructed on a slip-way, launched, and floated into place and completed in their correct position, the dredging being done with a clam-shell bucket.

The piles were cut to their exact length as shown by soundings and driven with a steam hammer and a follower. The tops of these piles stood approximately 5 ft. above the bottom of the caissons when they had been dredged out. The rest pier was supported on spuds and sheet piling driven outside it to form a mud-tight joint with the rock bottom. Twelve to fourteen feet in depth of concrete was then placed around the pile heads, the work being allowed to stand for fourteen days. The caissons were then pumped out and the balance of the concrete work completed in the dry. These caissons were not caulked, but were sealed on the outside with a canvas strip battened over the joints and two strands of rope laid between each course. High-power water-jets were freely used in loosening the material in the rest pier, which was of too hard a character for the last 3 or 4 ft. to allow the excavating bucket to grab hold.

Fig. 4. Counterweight Trunnion Pier Caisson Sinking into Position.

The method used for the under-water concreting, shown in *Fig.* 2, proved

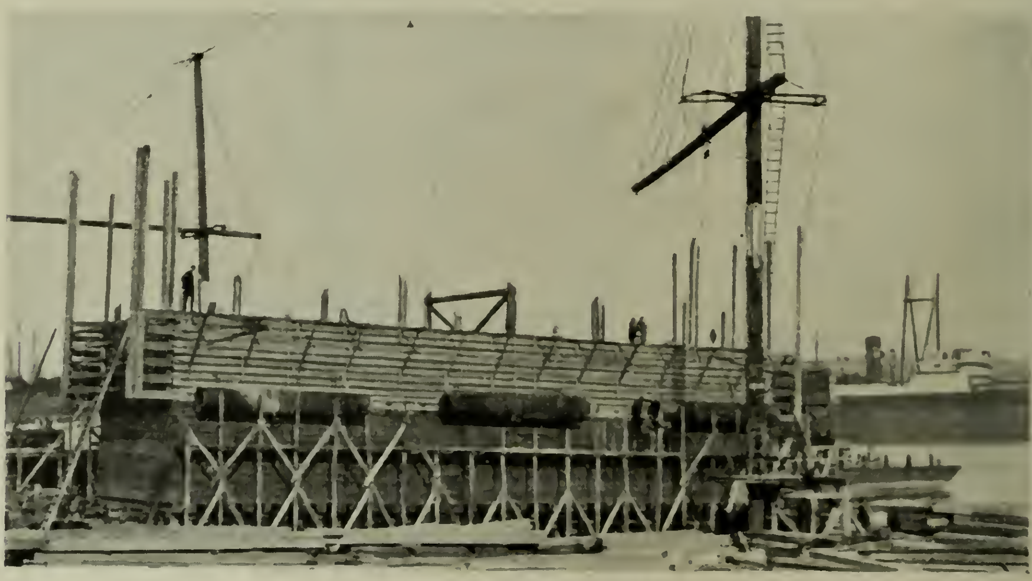


Fig. 3. Caisson for Counterweight Trunnion Pier ready for Launching.

highly successful. The principle involved is the depositing of concrete from a water-tight bucket by displacement of air instead of water. The bucket used in this case held 1 yd. and worked up and down between sliding leads in the manner of a pile hammer. It received its charge of concrete in its upper position, the doors were closed, and it was then lowered to its correct position under water under an internal air pressure sufficient to balance up the water pressure on the outside, the lower door being released from the surface and the contents discharged and the operation repeated. The work was carried out continuously until completed. The actual entire labour cost of mixing and placing was approximately 1.50 dollars per cu. yd. The water was afterwards pumped out from the caissons with no difficulty, and the concrete found to be of excellent quality after removing from 3 to 18 in. of laitance which had accumulated in the entire 12 ft. in depth of concrete laid.

The bucket used on the rest pier had not the extension used on the other piers, since no piles had been driven, and this naturally simplified the work. The Canadian patent on this bucket has been granted, and the English and American patents are pending.

Fig. 3 shows the caisson for the counterweight trunnion pier ready for launching. Since there was an insufficient depth of water at the end of the ways, and in order to give a temporary less draught, a false bottom was inserted at

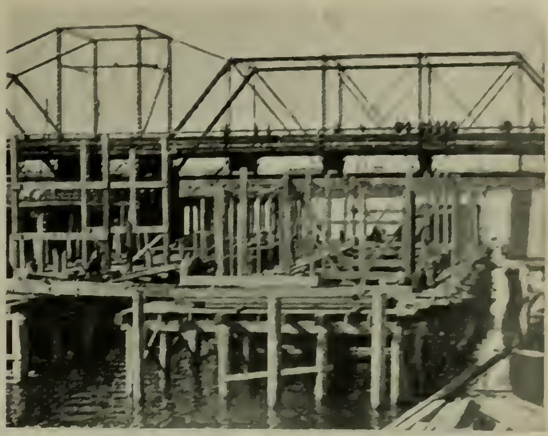


FIG. 6. MAIN AND COUNTERWEIGHT TRUNNION PIERS IN POSITION.

about the fourth course up from the bottom. The pontoons on each side were necessary for stability. The guides on each end of the caisson are holding it in its correct position when sinking. The end bracing upon the outside is to be noted. This was done in order to leave room for excavation and form work.

Fig. 4 shows the caisson leaving the end of the ways and gradually sinking to its correct depth for complete stability.

Fig. 5 shows the launching of the caisson for the rest pier. Note the peculiar construction at the front end where the caisson was cut out to fit the rock.

Fig. 6 shows the main and counterweight trunnion piers in position ready for building up.

Fig. 7 is a view of the counterweight trunnion pier caisson after pumping out.

FIG. 5. REST PIER CAISSON BEING LAUNCHED.

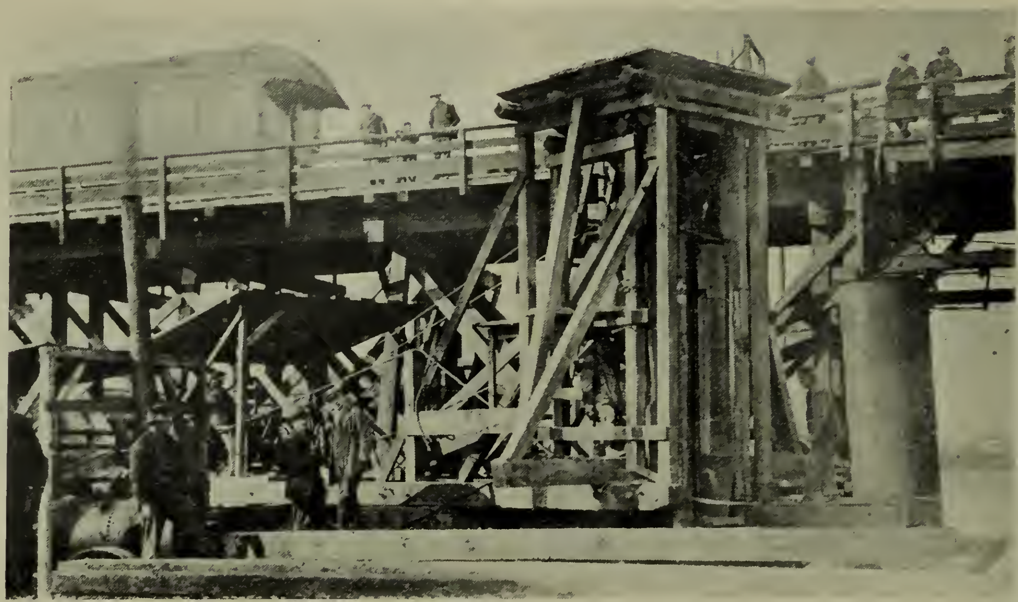


Fig. 8. Placing Concrete under Water.

Fig. 8 is a view of the concrete being placed under water.

Fig. 9 is a general view from the west. In the foreground, sheet piling is in progress for one of the small coffer-dams at the west abutment.

Fig. 10 is a general view from the east. The derrick in the foreground had a boom 180 ft. long, and was so situated that it handled all of the work on the east side of the harbour, namely, the east abutment and main and counterweight trunnion piers.

Fig. 11 is a general view from the south, showing the main and counterweight trunnion piers in position and the existing railway bridge in the act of swinging.

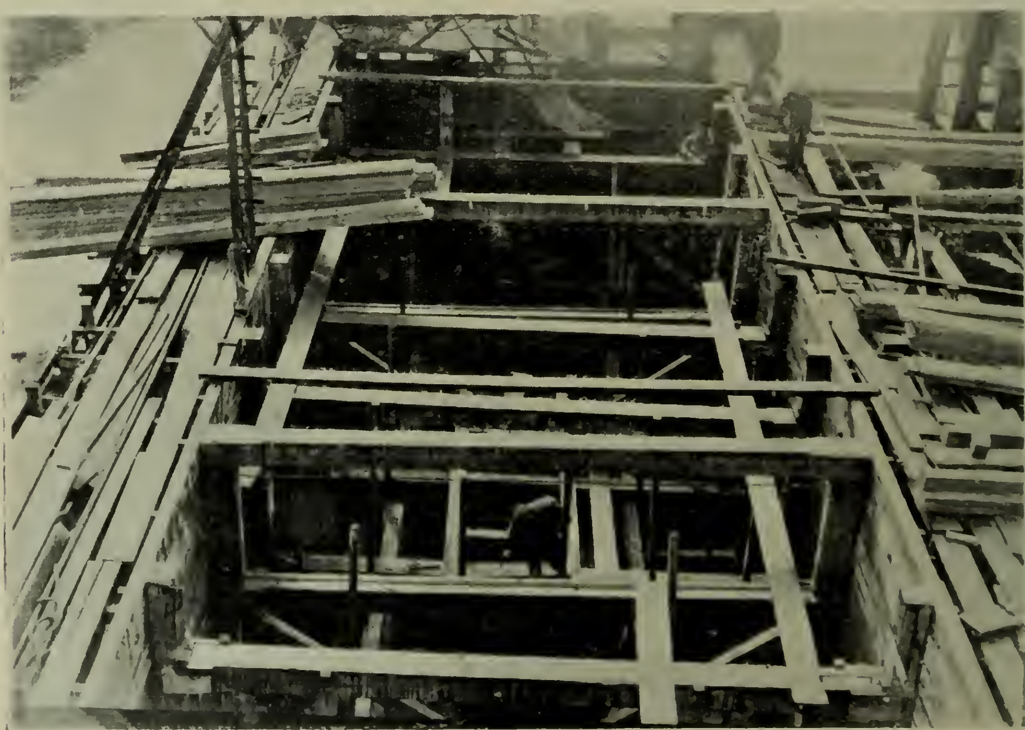


Fig. 7. Main Trunnion Pier Caisson after Pumping Out.

FIG. 11. GENERAL VIEW FROM SOUTH.

FIG. 9. GENERAL VIEW FROM WEST.

FIG. 10. GENERAL VIEW FROM EAST.

PATTERN STORE AT NORTHFLEET.

Early last year the Associated Portland Cement Manufacturers found it necessary to erect a new and enlarged Pattern Store at their engineering works at Northfleet. At that time it was practically impossible to get bricklayers, and such as were obtainable were very unsatisfactory owing to low output and high wages. Steel work also commanded extravagant prices. Accordingly it was decided to devise a simple form of concrete construction, which would eliminate as far as possible the employment of any skilled tradesmen, and at the same time be low in cost.

The overall dimensions of the building are approximately 132 ft. by 80 ft., and it is divided into eight bays, each 16 ft. wide and 80 ft. long.

The method of construction is shown on the drawing illustrated on p. 317, and consists of pre-cast reinforced concrete columns 9 in. square which were made on site and then lifted into position by means of a derrick pole. They were then grouted up on the foundation piers, which had been previously prepared. These columns are swelled out at the top, and have a recess formed to receive the ends of the roof principals.

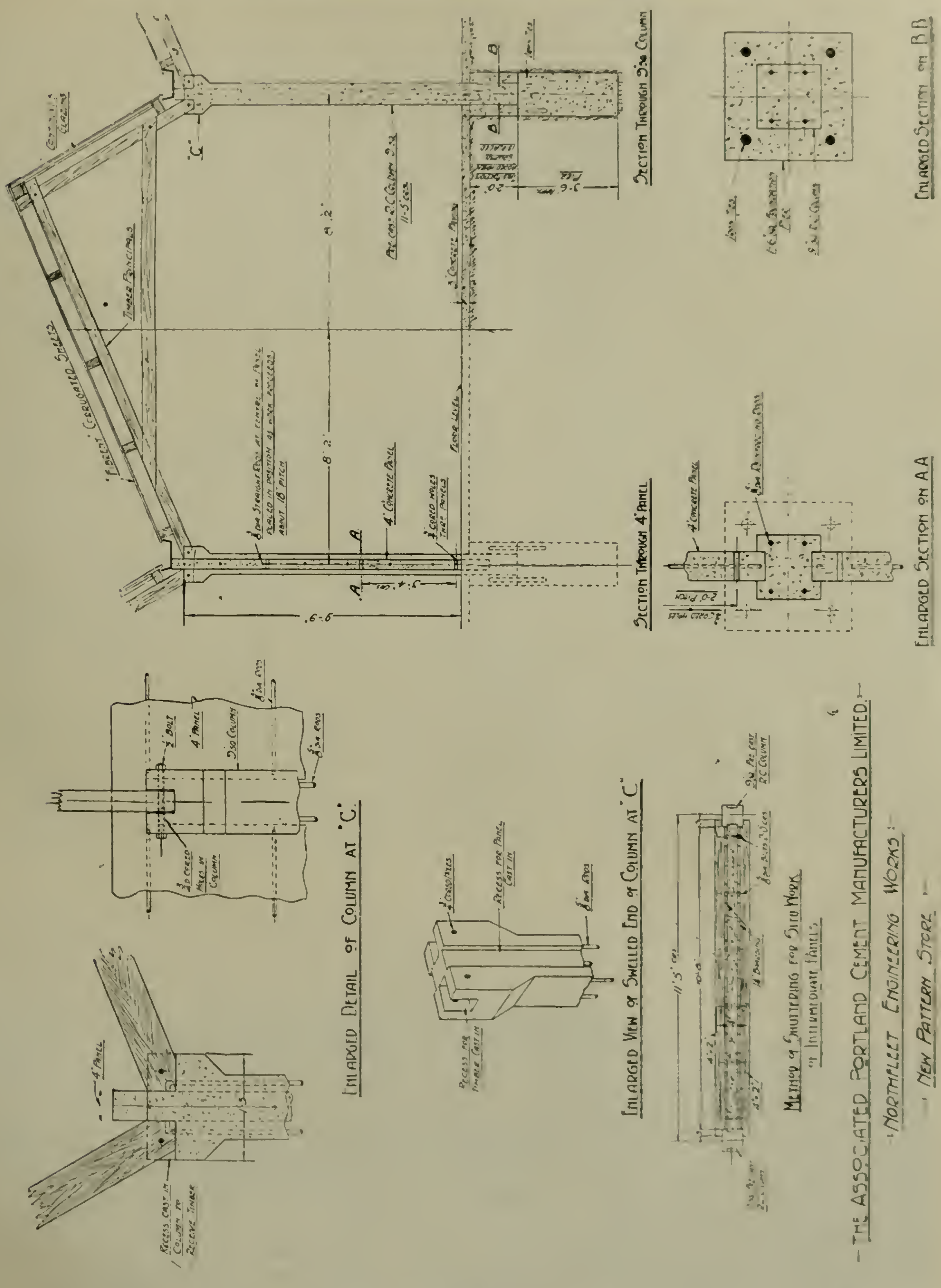
After the columns had been properly fixed, the intermediate panels were formed between them by means of shuttering and the concrete was poured *in situ*, in three lifts of about 3 ft. 8 in. each. All the panels being of the same size, the same shuttering could be used right through the job.

These panels are 4 in. thick, and are reinforced by means of $\frac{3}{8}$-in. dia. mild steel rods placed horizontally at 18 in. pitch. The concrete consisted of 5 parts of washed ballast, which contained the requisite quantity of sand passed through a $\frac{3}{4}$-in. screen, to 1 part of cement, and was mixed by means of a Winget concrete mixer of 3 cu. ft. capacity direct driven by a petrol engine.

In order to avoid the expense of steel work the roof was constructed in timber,

New Pattern Store at Northfleet.

and is covered with " Fibrent " corrugated sheets supplied by the Fibrocement Co. ; the north light, which is continuous, is, of course, glazed.



It was found that when the men got used to the method progress was rapid, and the cost, which works out at 7*d*. per cu. ft., compares favourably with other forms of construction, and justified the object for which the design was evolved.

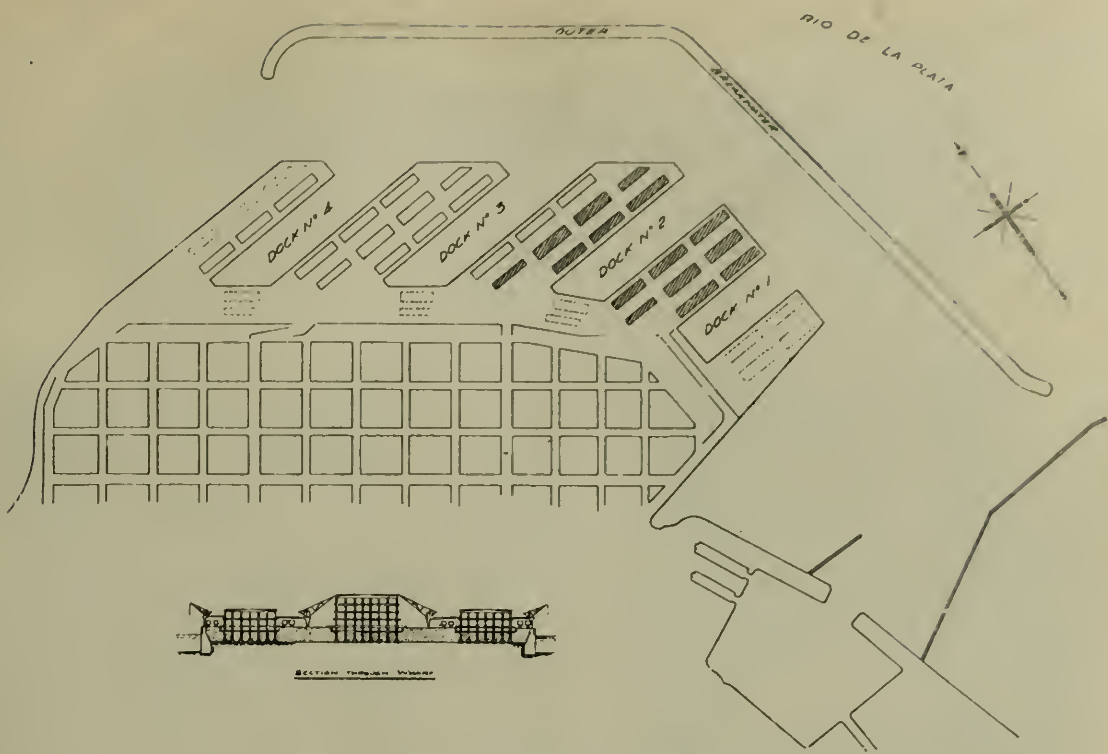
BUENOS AIRES PORT EXTENSIONS.

This important work was begun ten years ago by Messrs. C. H. Walker & Co., Ltd., the well-known London contractors, who have carried out a large amount of work in South America. The new port works at Buenos Aires involve the reclamation of about 400 acres of land and the construction of four new docks with quays constructed in mass concrete, which have a total length of over 6,000 lineal yards. The work also includes the building of transit sheds and warehouses covering about 100 acres of floor space. The total contract amounts to approximately five and a half million pounds. The engineers for the works are Messrs. Livesey, Son & Henderson, MM.I.C.E., of Finsbury, London.

The first of three extensive dams, having a length of over 2,300 metres, had to be constructed, and a large amount of excavation and filling was required before any of the quay walls or buildings could be erected. It was only possible, therefore, for the contractors to begin the reinforced concrete work shortly before the outbreak of the war, and, although they were able to carry on operations for several years in spite of the great difficulties due to hostilities, things became increasingly difficult, until the work had to be practically stopped during the last year of the war, as it was no longer possible to obtain the necessary materials to carry on the construction. As soon as possible after the Armistice operations were resumed, and the work has been proceeding ever since. We publish in this issue some recent photographs showing some of the reinforced concrete buildings which have been completed, and others which are in course of construction. The plans for the reinforced concrete work were prepared by Messrs. Edmond Coignet, Ltd., reinforced concrete engineers, of London.

An idea of the extensive employment to be made of reinforced concrete may be gathered from the statement that the works in this material involve some 200,000 cubic yards of concrete and about 18,000 tons of steel. The work is to include fourteen large warehouses, several stories in height, twenty sheds or hangars, about eighty subways connecting the various buildings, several bridges, and probably several granaries. Six of the warehouses are about 415 ft. long

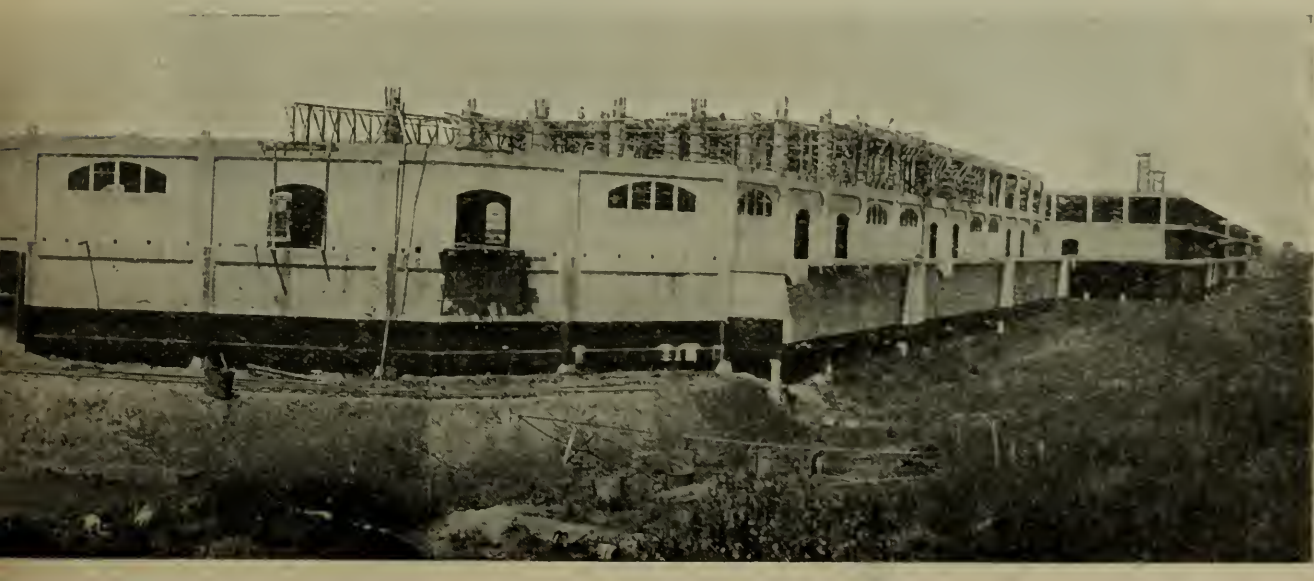
General View of Warehouses



Buenos Aires Port Extensions.

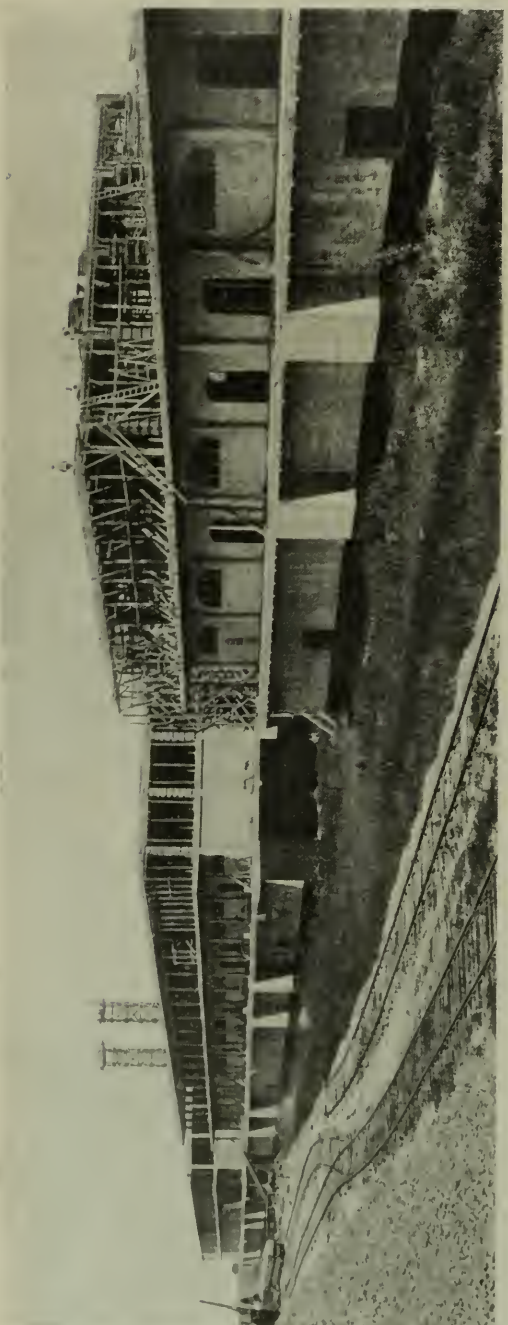
and 120 ft. wide. On each side of these warehouses and along the quays there will be altogether twelve transit sheds or hangars, each 354 ft. long by 98 ft. wide. The remaining warehouses are to be 354 ft. long by 69 ft. wide, and facing them there will be eight sheds 354 ft. long by 98 ft. wide. The granary buildings will probably be designed to accommodate in the form of bins for the storage of 20,000 tons of grain, and subways of considerable length will be required. The warehouses above mentioned, some of which are partly completed, will comprise altogether a basement, ground, first, second, and third floors and a flat roof.

The transit sheds or hangars, some of which are entirely completed (as shown

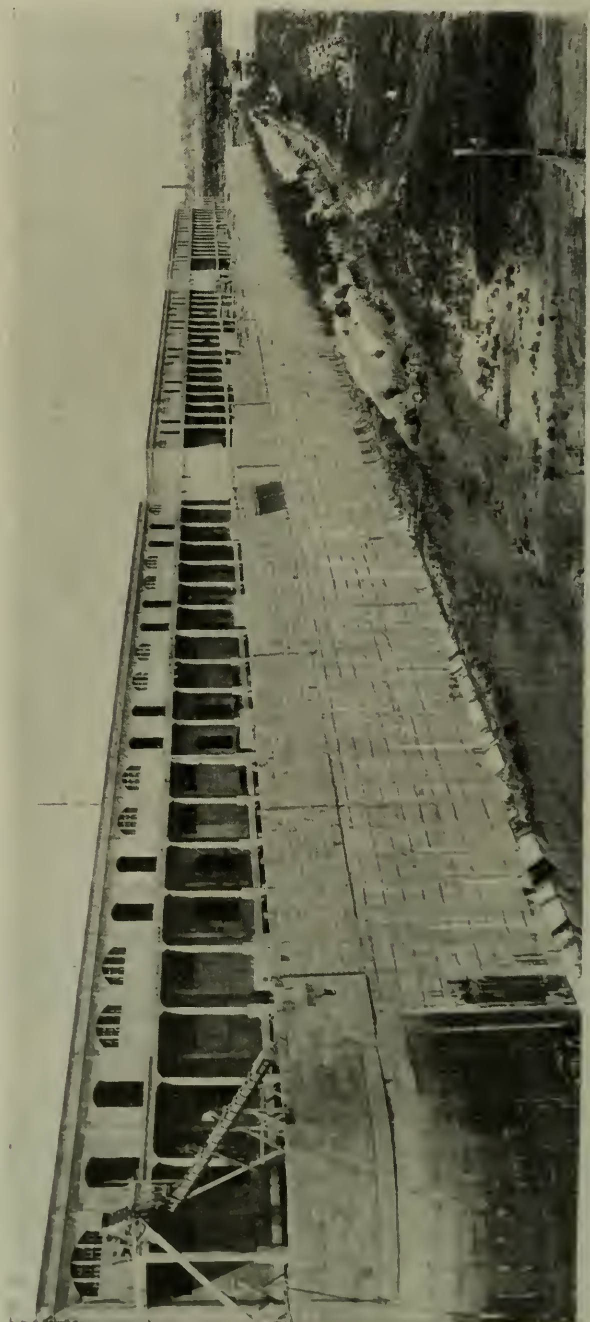


ngars in Course of Erection.

in the photographs), contain a ground floor, first floor, and flat roof. The whole of these buildings are in reinforced concrete on the Coignet system, including retaining walls, columns, floors, roofs, walls, stairways, loading platforms, bridges and subways. The work will no doubt require several years to complete. The total cost of the reinforced concrete work alone will amount to about a million and three-quarter pounds when all the buildings are completed. This is claimed to be a record, and to be probably the largest contract ever secured in reinforced concrete.

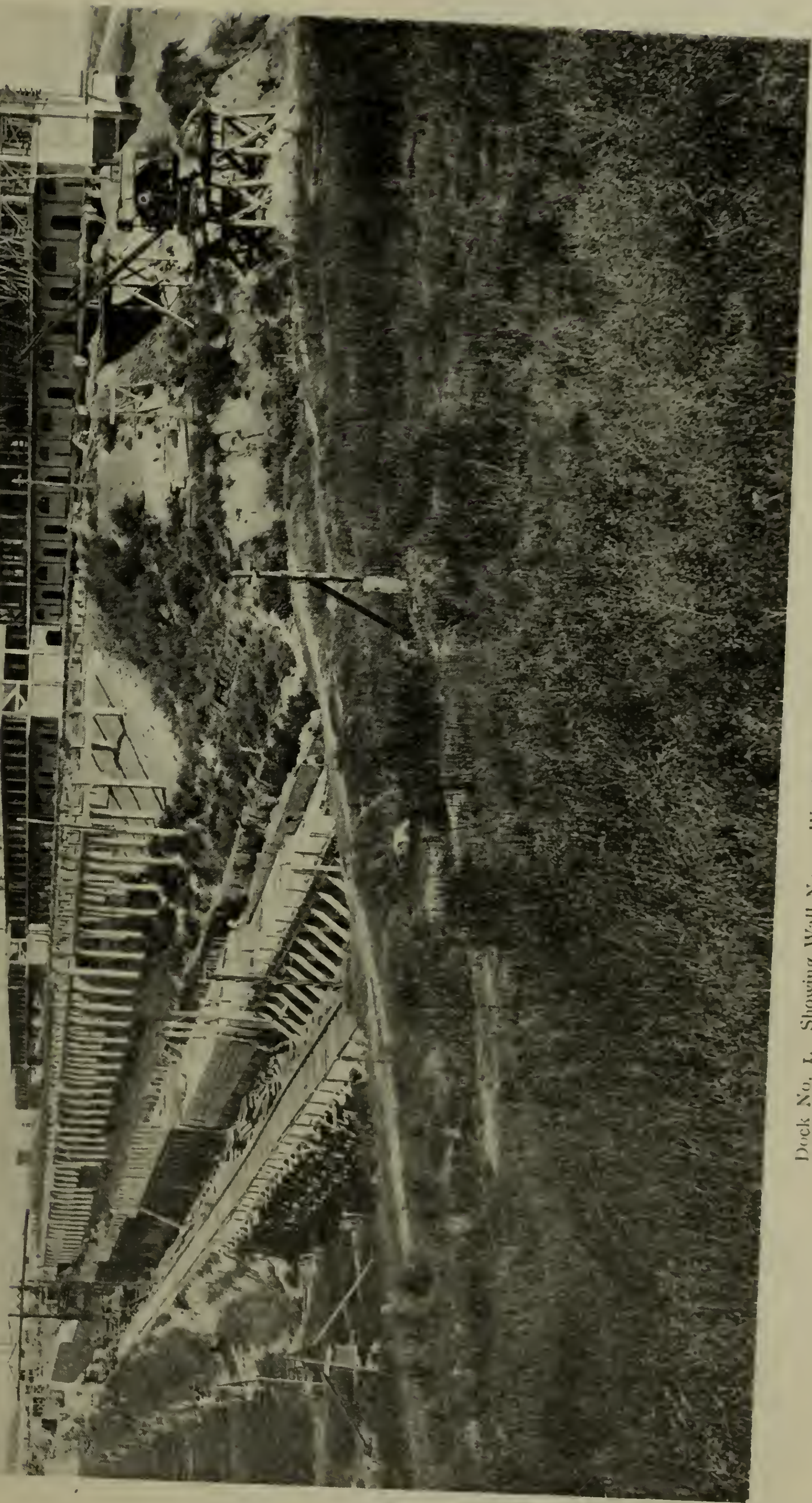


Reinforced Concrete Warehouses in Course of Erection.



Dock No. 1. Showing Reinforced Concrete Hangars completed.

Buenos Aires Port Extensions.



Dock No. 1. Showing Wall No. 9, Warehouses, and Foundations for Hangars.

BUENOS AIRES PORT EXTENSIONS. (*See page* 318.)

PROPOSED "INSTITUTION OF STRUCTURAL ENGINEERS."

AT a meeting of the Concrete Institute held at Denison House, Vauxhall Bridge Road, London, on March 23, the President, Mr. E. F. Etchells, who occupied the chair, said there had been established a London Association of Constructional Engineers. This was admittedly not a professional body in the sense that the Institution of Civil Engineers was, and the Council of the Institute had also received certain information with regard to the objects of another new professional body entitled The Institution of Structural Engineers, whose aims appeared to be identical with those of the Institute itself. Also, one or two letters had been received as to the action which should be taken by the Institute to meet the new conditions, which would be discussed by the Institute subsequently. The problem was that there were those who said that the Concrete Institute should continue as a scientific society, having its interests centred in concrete, and collecting within its membership civil engineers, chemists, physicists, architects, and quantity surveyors, and those who had interests centred around concrete ; on the other hand, there were those who said that the Concrete Institute had for many years dealt with materials other than concrete alone—materials used in conjunction with concrete, such as steel—that many of the members were structural engineers, and that architects were something more than structural engineers, The matter promised to be highly controversial, and the Council would welcome any expression of opinion from members, either to the effect that the Institute should continue on the present lines, or that it should change its title to the Institution of Structural Engineers. A special Council meeting would be called on the following Thursday, and, depending on their decision the question would be brought before the general body of members for their decision also. If any change were to be made it would only be made after confirmation by a general meeting.

A paper was then read by Mr. S. F. Staples, M.Inst.C.E., M.I.N.A., on "Floating Docks."

ANNUAL GENERAL MEETING.

AT the Annual General Meeting, held on April 27, the President announced that the Council would probably recommend the members to agree to the alteration of the title of the Institute to "The Institution of Structural Engineers, incorporating the Concrete Institute."

The Medal of the Institute was presented to Professor F. C. Lea, for his paper on "The Modulus of Elasticity of Concrete."

The Annual Report of the Council for the year 1921–22 was adopted.

The President announced the election to the Council of Mr. Alex. C. Meston.

Mr. E. Fiander Etchells was re-elected President for the session 1922–23.

Among the new members elected were Mr. Paul Waterhouse, P.R.I.B.A., and Mr. John Murray, F.R.I.B.A.

CONFERENCES AT OLYMPIA.

On this and the following pages we give reports of the conferences held at Olympia, under the auspices of the Concrete Institute, during the Building Trades' Exhibition :—

EDUCATION AND RECENT DEVELOPMENTS IN THE INDUSTRY.

At the first of the gatherings, Mr. E. Fiander Etchells (President) opened a discussion on (1) "The Training of the Concreter," and (2) "Recent Developments in the Industry."

Speaking on the first subject, he said the Concrete Institute had hoped by this time to have had in hand a large scheme for the training of the concreter, but there was very little likelihood of there being employment for concreters after they were trained, in the present state of the industry. Therefore, it would seem to be unwise to train a number of men for whom no employment could be found. The many systems of concrete construction which claimed to dispense with the necessity for skilled labour had an injurious effect upon the industry, and now they were reaping the harvest sown by those who made extravagant claims. He believed, however, that concrete would hold its own till the end of time. The advantage of concrete was not that it wanted unskilled workmen, but that labour could become skilled quickly, The Concrete Institute was ready to receive suggestions as to methods of training concreters so that there might be a craft of concrete just as there was of bricklaying and other skilled trades.

In dealing with the second subject, he said recent developments had manifested the necessity for curing concrete blocks before use, the absence of which had been responsible for much of the unsatisfactory results in the past. He also referred to the modern trend towards the more extensive use of mechanical mixers and the mechanical handling of materials, for which light cranes had been used with great success. Another change was in regard to the closer examination of the endurance limit of steel. There was great doubt thrown at one time on the existence of the endurance limit in metals, but investigations by improved machines had shown that it did exist, and for mild steels and wrought irons it might be taken at about half of the primitive elastic limit.

With regard to the method of designing reinforced concrete, there had been great developments. One of the further stages was the paper read by Dr. Oscar Faber on the calculated effect upon a pillar of the flexure of the beam. It seemed likely that all future designers would have to take that into account. Mr. Harrington Hudson was working on the same problem, and attacking it by different means. So important were these investigations, that they would have an effect on all future reinforced concrete design.

With regard to materials being used, there were very reliable grades of British Portland cement, which were the most reliable in the world.

Discussion.

Mr. W. J. H. Leverton said it was of the utmost importance that the Institute should press on with a scheme for the training of the operatives in the concrete industry, and that training would, he thought, negative Mr. Etchells' remarks about the shortage of work by creating a greater demand.

Mr. Auden said in America considerable use was made of small depositing chutes, which might with advantage be more widely adopted in this country ; by the use of such appliances economics of as much as 20 per cent. were made.

Mr. Harrington Hudson said he would like to endorse the statement of Mr. Etchells as to the excellent quality of British Portland cement. Referring to the training of concreters, he said a single batch of bad concrete might seriously impair the strength of a whole structure, and it would be well to realise the responsibility of the operatives. The designer could rely on the quality of the cement and reinforcement, but the quality of the concrete had to be left to the operatives and foremen on the job, and if they were not efficient the designers' attempts at economical design would be futile.

Mr. Ness also dwelt on the necessity for training the workers. Referring to the use of high-tension steel, he said the point was a debatable one, but in cases where complicated reinforcement was used, the use of high-tension steel enabled smaller bars to be used, with a consequently greater possibility of getting the concrete thoroughly around them.

Mr. O. Lee said from his experience in concrete work in India during the past fifteen years, what was wanted was trained foremen and supervisers. He had had considerable difficulty in engaging foremen owing to the fact that there was no method of judging their qualifications before they were actually at work, and he thought the Institute could do a great deal of good by granting a certificate to qualified men. He also emphasised the necessity for co-operation between architects and engineers in designing buildings.

Mr. Etchells endorsed the previous speaker's suggestion that a certificate might be granted to foremen who had passed an examination.

In reply to a remark by Mr. Holden expressing the opinion that a training scheme might be arranged with the aid of the technical schools throughout the country, Mr. Etchells said the Institute was at present considering the formation of local centres for the purpose.

CONCRETE ROADS AND BRIDGES.

Dr. Oscar Faber, O.B.E., opened the discussion at the second conference, when the subjects were (*a*) "Concrete Roads," and (*b*) "The Use of Reinforced Concrete in Highway Bridges."

CONCRETE ROADS.

Dealing with the first subject, the lecturer said he was firmly convinced that the concrete road was the road of the future, but he was equally certain that some of the concrete roads as they were being constructed to-day invited failure and discredit which would throw back their development for a very long period unless immediately checked.

The concrete road had principally three functions :—

(1) To distribute point loads over a sufficient area of surface to enable the soil to carry the load without indentation or subsidence.

(2) To provide a hard-wearing surface.

(3) To resist frost and other natural disintegrating influences.

As regarded (1), an experienced engineer could estimate with sufficient accuracy the bearing capacity of the soil and the bending moments which point loads would throw on to the slab. He had seen roads with peat or marshy foundations where a passing motor had caused the road to settle an inch or more under the wheels of a loaded lorry, and to spring back to its former level after the lorry had passed—owing to the springiness of peat underlying the road. It was clear that the bending moments produced in a concrete road constructed in such places might be ten or twenty times as great as those produced in roads with a non-yielding bottom. When for any case the bending moments had been estimated, the quantity and kind of reinforcement had to be determined, and in many cases the quantity of reinforcement had been totally insufficient. It was clear from the elastic problems underlying the behaviour of a point load on a continuously-supported slab that the deflection of the road would be one of double curvature, the portion immediately under the load being concave upwards and the portions at some distance from the load being concave downwards. It followed that a double layer of reinforcement—one near the upper surface and one near the lower surface—was required if the fracture of the concrete was to be avoided, and in his opinion this was quite necessary on any roads other than those constructed on rock. It was the fashion in many quarters to use a mesh reinforcement for all roads, but he thought that was commercially a mistake. Commercial round rods could be obtained to-day for about £10 a ton, and most of the special wire mesh supplied for roads cost £50 a ton or thereabouts, though the fact was frequently hidden by the quotation being per square yard, so that for the same price per yard super of road five times as much commercial round steel could be provided without increasing the cost of the road. In his view, it was infinitely better to have five times the quantity of steel and stress it to a low stress instead of a very small quantity of steel stressed to about five times as great a stress, even if it could be shown that the steel in the wire mesh had a higher tensile strength than commercial mild steel, because the higher the stress in the steel the greater the tendency to form hair cracks in the concrete and to admit water, which under the action of frost would ultimately lead to disintegration of the concrete under the special conditions which applied in the case of roads.

As regarded the second function, of providing a hard-wearing surface, the problem was in his view one for legislation. If roads had to be designed to carry six or seven ton wheel-loads on steel tyres, as might happen, for example, in the case of a boiler wagon on steel wheels, then the community had to face an excessive cost for its roads, both initial expense and upkeep, and probably a steel surface was the only one which would resist that kind of treatment without being damaged. If, on the other hand, legislation were introduced prohibiting the use of steel tyres for, say, wheel loads of half a ton or over, which would still admit of light farm carts and machinery remaining as at present, then the cost of roads and their upkeep could be much reduced, and, as rubber tyres, especially pneumatic tyres, reduced the tractive effort very considerably and had already been adopted by nearly all the great carrying firms, there could be little hardship in compelling the few who remained and who were responsible for damaging roads so greatly to convert to rubber wheels within a period of, say, three years. It was a significant fact that in the United States, where concrete roads had been such a great success, steel-tyre vehicles were practically unknown.

In his view, ordinary concrete was quite unsuitable for the wearing surface of a road, and a special concrete having a crushing strength of 5,000 lb. per sq. in. was necessary. With rough granite, sand, good grading, and a careful control of the quantity of water to give maximum strength and minimum porosity, that was easily effected under technical supervision.

As regarded the resistance to frost and other natural disintegrating influences, absence of porosity was the most important factor. To achieve that, it was desirable that the stone selected should have the minimum porosity. Some limestones and sandstones would absorb 10 per cent. to 18 per cent. of their weight of water, and were quite unsuitable for the wearing surface of a concrete road; in his view, no stone which would absorb more than 3 or 4 per cent. of its weight of water should be used.

In the United States a large proportion of the roads was being laid without reinforcement. The bulk of those roads had, however, very much lighter traffic than in this country, and such roads would not stand here unless they were made so very much thicker than a successful reinforced road that the balance of cost would be in favour of the reinforced road, which would have the additional advantages of flexibility, absence of cracking, etc. With plain concrete roads expansion joints were unnecessary, because the concrete practically formed its own joints by producing contraction cracks at intervals, but with a reinforced road adequately reinforced contraction cracks should not occur, and such roads should have expansion joints not farther apart than about 50 ft., and those joints required care in design.

Objections to concrete roads had been taken on the score of inaccessibility of drains, pipes, mains, etc., but that was largely an exaggerated difficulty. It was easier to cut through, say, a 6-in. or 8-in. reinforced road than to cut through the ordinary street in a big city, where wood block paving might frequently have 18 in. of concrete under it. The cutting of the reinforcement presented no difficulty with an oxy-acetylene flame, any individual rod being easily cut in about five seconds on exposure to the flame, and the lapping of fresh rods against the old rods left projecting enabled a secure and strong joint to be made afterwards. In cities, subways to accommodate drains, pipes, electric mains, etc., would undoubtedly be a development in the near future, and would obviously pay for themselves in a very few years; the question of ventilation to prevent explosion due to leakage of gas, etc., was a matter not beyond solution by modern engineering science.

It might be thought that some of the requirements he had outlined might be expensive luxuries, but he was fully convinced that they were necessities for a road designed to last. He had already, as consulting engineer, designed and constructed several roads in which they had all been carefully complied with, and the roads in question, which were carrying very heavy traffic, did not show the slightest sign of wear or injury. As regarded cost it was doubtful whether if commercial steel were substituted for any of the patent mesh reinforcements there need be any extra cost at all, even though the quantity of reinforcement were many times as great. As regarded the cost of laying, in his experience straight rods could be laid more cheaply than commercial mesh reinforcement delivered in rolls, which took a good deal of holding accurately in place during concreting.

REINFORCED CONCRETE HIGHWAY BRIDGES.

On this subject the lecturer said all the following types of reinforced concrete bridge had been successfully used: the arch with the highway over it; the arch with the highway suspended from it; the bow-string girder, which was really the same as the second type with the exception that a tension member was provided to resist the whole thrust from the arch instead of relying on the soil to form movable foundations; and the girder or beam type of construction.

Where the circumstances allowed the arch type was to be preferred for reinforced concrete, because the concrete being especially strong in compression the function of the reinforcement in an arch bridge was confined to accidental bending stresses so far as the primary structure of the arch was concerned. In other words, in the case of an arch, the concrete without reinforcement carried the great bulk of the compression and the tension member was supplied by the earth, whereas in an ordinary girder a tension member approximately equal in strength to the compression member had to be supplied in addition.

For this reason also, the arch type of construction was often lighter and cheaper than any other, and frequently enabled bridges of the arch type to exceed in span what would be a limiting figure for bridges of the girder type when dealing with a relatively heavy material like reinforced concrete. It would be interesting to compare the relative advantages of bridges of steel and reinforced concrete for highways, and it was necessary to differentiate between steel bridges left with the steel exposed, except for coatings of paint, and steel bridges protected with concrete against corrosion. In the first case, the steel bridge would, of course, be much lighter than in the second, but would, on the other hand, be subject to a continual upkeep expense for repainting. Comparing reinforced concrete bridges with unprotected steel bridges, experience showed that for moderate spans the reinforced concrete was cheaper or equal in cost, but that where the span became excessive the steel bridge became cheaper because of its greater lightness. The exact span at which the steel bridge became cheaper than the reinforced concrete one depended on the type and on the ratio of depth to span, arched bridges being cheaper in reinforced concrete up to spans of 300 or 400 ft., while bow-string girders and other girder types of bridges were cheaper in reinforced concrete up to spans about 150 ft. Spans greater than those were the exception, and for general work it might be accepted that the reinforced concrete bridge was cheaper than the unprotected steel bridge, besides having the very great advantage of eliminating painting and other upkeep expenses. Steel bridges protected with concrete contained roughly the same amount of concrete and centering as a reinforced concrete bridge, and about three times the quantity of steel, and were always more expensive than reinforced concrete bridges for all spans.

By way of example of the cheapness of reinforced concrete bridges as against steel, in 1914 he designed a viaduct 2,400 ft. long containing a skew bow-string girder bridge of 70 ft. and several girder bridges of 40 ft. span, the rest of the construction being trestle constructions of 20 ft. span, and though estimates for the steel were obtained from about twenty British and about five Continental firms, the reinforced concrete structure was 27 per cent. cheaper, though it provided for a substantial concrete deck instead of $\frac{3}{8}$-in. steel troughing, and the relative life of the two constructions was obvious. In addition to the advantages already mentioned, reinforced concrete bridges had a considerable advantage as regarded vibration, surging, and deflection. It was a fact constantly verified that, whereas steel bridges under tests developed approximately the calculated deflection, reinforced concrete bridges under test generally developed only a small fraction, frequently only a quarter, of the calculated deflection, The reason was largely that whereas the tensile strength of the concrete was ignored in the calculations on the score of safety, the concrete frequently exerted its tensile strength without fracture over a considerable portion of the structure, and so gave a considerably greater moment of inertia than was used in the calculations.

It was sometimes stated that the advantages of steel bridges over concrete lay chiefly in the greater ease of erection, but in the case of highway bridges over railways, canals, or roads the difficulties in connection with the erection of concrete bridges were generally quite easily overcome. Indeed, it was noteworthy that in some places where the difficulties might have been anticipated to be distinctly above the average concrete bridges had been successfully adopted. For example, the bridge carrying the road and tramways over King's Cross Station, where head-room was very cramped and no interference with the railway traffic could be tolerated, a reinforced concrete bridge was successfully constructed. He had just designed a large concrete bridge at Huddersfield over a canal where the total thickness of the construction between the top of the deck and the underside of the beams was only 18 in. on a 65-ft. span, and the falsework was so designed that only 3 in. additional depth was required during construction so as not to interfere with the canal traffic.

In conclusion, the lecturer referred to the system under which the design and construction of bridges were frequently dealt with, namely, by the invitation of competitive designs and estimates, which, he thought, could not be too severely condemned. He suggested that the proper method was for the engineer either to prepare his own design and quantities, so that all tenders might be comparable with an agreed design, or that a consulting engineer should be called in.

Discussion.

In the ensuing discussion, Mr. Oliff Lee said in connection with the erection of a number of small bridges on unmetalled roads, where they carried about one-ton axle loads, he had found the three-hinge bridge cheapest; it was extremely simple to erect, but he found the actual volume of concrete used was the same as for reinforced concrete design; the span was 40 ft. clear. Another thing he had tried was erecting bridges with suspended centering, and he found it extremely simple. The sections were cast in a length which could be handled, and were limited in weight to 20 tons. They were lowered from suspenders and concreted up joint by joint. That plan had saved a lot of money.

Mr. Shelt said undoubtedly the best road was the one where the whole length was laid in one operation. He did not think the three-course principle should continue, but the whole thickness of the depth of the road should be laid in one operation so that there were not the different settings of the three layers of concrete.

Mr. Walker said he did not think the steel put in to provide for the stresses due to temperature was the most serious thing. The concrete was put in when wet, and if kept wet there would be no contraction. In the ordinary course of making a road, the concrete was laid and water put on to it to keep it wet as long as possible. If the concrete were not kept wet there was sure to be contraction, and contraction due to loss of moisture was more serious than that due to a fall in temperature, because it occurred when the concrete was weakest. A road should be reinforced both longitudinally and transversely.

Mr. Andrews said Mr. Walker had made a real point in drawing attention to the fact that the most serious trouble was not the temperature expansion and contraction, but the setting contraction. He (the speaker) was inclined to think they sometimes overestimated the temperature effect, failing to realise that concrete was a comparatively bad conductor of heat, and therefore the effect of changes of temperature would be much slower on concrete than on exposed steel.

Mr. Lewis said he had recently had the opportunity of inspecting one of the longest concrete viaducts in the world in America, in which expansion joints of $1\frac{1}{4}$ in. were spaced about every 150 ft.; he had been informed that they had been found too much, and that half would probably have done.

In reply to the discussion, in which Mr. F. G. Keene and Mr. Langston also took part, the lecturer said the difficulty of making the concrete in roads carry all the stresses, leaving the steel to look after temperature and other stresses, was the excessive thickness which would be necessary.

THE LIFE OF CONCRETE WORKS.

At the third conference, Mr. G. C. Workman opened a discussion on " What Life can be Assigned to Works of Reinforced Concrete for the Purpose of Government Loans ? "

Mr. Workman said so far as he had been able to ascertain reinforced concrete based on scientific methods of calculation was introduced into this country about 1900. In a general sense, therefore, it might be said the oldest structures erected in the country were about twenty years old. In France, however, there were scientifically-designed buildings thirty years old. It was strange to find that in spite of the now well-established lasting qualities of reinforced concrete, and of the fact that a large number of such buildings and other structures had been created by all the Government departments, the Ministry of Health and the other departments concerned with the granting of loans on reinforced concrete works still held the view that it did not offer the same guarantee of permanent strength or durability as the older forms of construction, such as ordinary concrete, brickwork, or steel. The Ministry of Health, in a general sense, was prepared to grant a period of twenty years for repayment of loans for reinforced concrete work, each case, however, to be judged on its own merits. That period concerned more particularly reservoirs, tanks, pipes, and the like. He was given to understand, however, that probably a much longer period would be allowed in the case of buildings. At the Ministry of Transport he was informed that for culverts and the like thirty years would be granted, for arch bridges twenty-five years, and for flat bridges twenty years. He had gathered the impression that the new ministries dealing with the question were not averse to reinforced concrete and fully recognised its strength and durability, but appeared to be still labouring under the difficulty that it was impossible to find in the country any work older than about twenty years. They argued, therefore, that it would be unwise to grant the same period of loan for reinforced concrete as for older forms of construction until it was possible to point out a number of structures which had lasted the full thirty years without showing undue signs of decay. To deprive the public of reinforced concrete by penalising the material with a shorter period of loan than the older materials was not in accordance with present-day economical requirements. It was obvious that many towns and municipalities could not see their way to use reinforced concrete until they felt sure they would be allowed the same period of loan as for the older forms of materials. It had been abundantly demonstrated that concrete increased considerably in strength with age, and that steel bars embedded in good concrete did not rust. Unprotected steel constructions required constant attention and were liable to rust and perish, so that it was unreasonable to grant a longer period of loan for steel structures.

Having referred to many reinforced concrete works carried out by public bodies and private companies, the speaker touched on some of the older reinforced concrete works around Paris, including the Church of St. Jean de Montmartre, constructed on the Cottancin system in 1897 ; the pumping station at Clichy, built on the Coignet system twenty-nine years ago ; and the large sewage pipe at Acheres, also built on the Coignet system twenty-nine years ago. All these structures were in an excellent state of preservation. In France the city of Grenoble made a reinforced concrete water pipe 330 ft. in length and 12 ins. diameter so far back as 1886 ; it had required no repair, and had given every satisfaction. In 1891 large reservoirs and filters were constructed at Libourne on the Coignet system ; in 1893 and 1894 many miles of pipe were constructed on the Bonna and Coignet systems at Acheres ; in 1892 a large arch bridge was constructed on the Hennebique system at Chatellerault ; and in 1894 several railway bridges and extensive viaducts were constructed at the Gennevilliers gasworks, near Paris. All those works were now in an excellent state of preservation, and were, if anything, carried out with a smaller factor of safety than that used in this country at present.

The question of loans for reinforced concrete in tidal waters was generally provided for in Parliamentary bills ; it was noticeable, however, that in such cases the period of repayment of loan was usually very considerable, and would not in any way restrict the use of reinforced concrete as compared with other materials.

In the United States there were a number of reinforced concrete structures more than twenty years old, and there was no discrimination against the material so far as the question of duration or repayment of loan was concerned. In France its use was encouraged in every possible way, but in this country city and municipal engineers, knowing that any scheme they might put forward in reinforced concrete might be liable to a short period of loan, were discouraged from using the material. He had been informed of a scheme for a reservoir for a rural district council where the tenders showed a saving of £1,800 in favour of the reinforced concrete work, but it was decided to adopt mass concrete as it was considered that the shorter period of loan for the reinforced work would more than counterbalance the saving which would have been effected in the original cost of the reservoir. He believed the Ministry of Health was beginning to feel that its views were perhaps too conservative, and that it would welcome a certain amount of gentle persuasion. He was of opinion, therefore, that a deputation from the Concrete Institute to the Ministry would probably have a beneficial effect so far as Government loans were concerned in placing reinforced concrete on the same level as any other form of construction.

Discussion.

Professor E. R. Matthews said he had found reinforced concrete sewers were used in most of the important cities in America, and the City Engineer of Philadelphia had informed him that he had carefully inspected sewers which had been in use for twenty years and had found that the concrete had not deteriorated in the least.

Mr. E. Fiander Etchells drew attention to specimens of reinforced concrete which had been buried for fifteen years. Where the reinforcement had been in ballast concrete it was quite bright, and in some brick concrete it remained untarnished, but where it had been in coke breeze it had rusted.

Mr. Shingleton and Mr. Woods also took part in the discussion, and urged that the loan period for reinforced concrete work should be extended.

CONCRETE BUILDING CONSTRUCTION.

Mr. E. S. Andrews presided at the fourth and final meeting, when the subjects for discussion were (*a*) Concrete Block Building; (*b*) Reinforced Concrete Floors, and (*c*) The Use of Pre-cast Work in Building Structures.

CONCRETE BLOCKS.

Mr. Andrews said during the past few years concrete had had the opportunity of its life, and had responded well to the opportunity. At the same time many were apt to be disappointed at the fact that there was still a large number of people who regarded concrete as an absolutely new form of construction, and who looked upon anyone embarking upon an enterprise involving concrete as doing something of a highly experimental and problematic nature. He would like to see these bogies set aside once and for all. Many people imagined that concrete blocks could only be used to fill up the spaces between pillars, but good concrete construction was as good as brickwork, and in most respects considerably better, and certainly it was stronger. What, however, was required was a standard specification for concrete blocks, and the Concrete Institute was endeavouring to work out something of the kind. It was up to the manufacturers of blocks and all interested in this kind of construction to see that they maintained a high standard of production. If they could get a good rigid specification that people could order to and have tested, they would have gone a good way. It was necessary that there should be standard specifications for both waterproof and permeable blocks. As to the manufacture of blocks, no one would deny that the best block was made by the wet process; where the block was cast with sufficient water in the mould and allowed to set. The objection to the wet process was that either there had to be a very large number of moulds or that it took a considerable time to make a large number of blocks. In the semi-dry method the concrete was not made so wet; it was mixed in the machine and taken almost immediately to another place for curing, so that the machine was available for mixing further blocks. There was a danger with that process that too little water might be allowed, with the result that the concrete would not harden properly; but blocks were made with perfect success by that method so long as sufficient water was allowed for the hydration of the concrete.

Discussion.

Mr. Gibson pointed out that the Ministry of Health had issued a standard specification for concrete blocks for houses, which he believed met the case. The insulating properties of the breeze blocks were fully recognised in that specification.

Major Smith said in his opinion the concrete block building was the solution for economic permanent construction, provided that the design of the blocks was correct, and the manufacture and erection was right. Provided that the concrete of breeze block was made with clinker its strength was equal to that of stock bricks, and if the breeze blocks were bonded properly to the outside wall they would get all the strength they required even if the inner wall gave no strength at all. He agreed with the necessity for having sufficient water in the concrete blocks at the time of manufacture. Tests made on blocks made on the semi-dry method showed them to have less strength than those made by the wet process.

Mr. Oliff Lee gave the results of his experience in Mesopotamia in regard to building with concrete blocks and said that having tried certain systems he designed a block of his own. He started by making as few units as possible. He decided to have a room which could be measured in multiples of four, and had pillars for each division, and made blocks 16 in. by 8 in. by 9 in. for the intervening spaces. The blocks had a tongued groove so that they would always fit up against the pillars. The pillars were 4 ft. apart, and he used 2-in. slabs between them, one inside and one outside, which gave him a 12-in cavity wall. He found the houses worked out considerably cheaper than other methods he tried.

Mr. Shingleton pointed out that the prejudice against concrete blocks was not in regard to their strength but in respect of their appearance. Also, builders and contractors found they could not use them so readily unless for type-designed houses where there was repetition of the same blocks.

Mr. T. J. Clark referred to the coloured concrete houses at Liverpool, which, he suggested, were of very great interest as showing what could be done in that direction.

Mr. Andrews, replying on the points raised, said the crux of concrete block construction lay in the blocks being well made. The Concrete Institute did not think the specification of the Ministry of Health met the case altogether, and he would not be satisfied with any specification which did not give minimum strengths for both types of blocks. He had no definite figures about lime concrete blocks, but he saw no reason why they should not be used ; he doubted, however, whether it would be commercially worth while. Lime plaster would help, but would not entirely eradicate the difficulty of moisture.

REINFORCED CONCRETE FLOORS.

Passing to this subject, Mr. Andrews said there was no doubt reinforced concrete was the very best form of construction, and was very largely used. He favoured an ordinary reinforced concrete floor reinforced with ordinary mild steel. In some conditions it was desirable to have a self-centering floor, as it facilitated the work of construction. If special floors were not considerably more expensive he had no objection to them. His personal opinion was that mild steel was both effective and economical. If special steels were to be used, he was in favour of the steel which was strong because of its chemical contents rather than a steel which was strengthened by working.

Replying to the discussion, he said he did not know why mushroom floors were not used in this country ; there was plenty of information regarding them available, and he saw no reason why they should not be adopted, although, of course, they involved greater niceties in calculation.

A SPECIFICATION FOR CONCRETE ROADS.

In these days of financial stringency it is so essential that public works which involve the expenditure of the money of the taxpayers and ratepayers should not be allowed to develop on haphazard lines that we welcome the issue of a " Suggested Form of Specification for Concrete Roads." This type of road is now so far past the experimental stage that certain general principles have been evolved which, so far as present knowledge goes, are necessary to success, and it is the results of experience in America and in this country which are embodied in the suggested specification. The extent to which concrete is being used in the big arterial road schemes now in course of construction up and down the country, and the success which has attended the concrete roads at Southwark and elsewhere, are convincing proof that there is a great future for this class of road, and that it must inevitably claim the serious attention of other municipal and road authorities. It is to the Surveyors and Engineers of the latter bodies, rather than to the already converted, that we think the suggested specification will be of most service, giving as it does a complete résume of the methods which have been found most satisfactory in actual practice. The specification is sectionised under the headings Materials, Preparation of the Existing Surface, Concrete (proportions, measurement of materials, method of mixing, consistency, etc.), Placing the Concrete, and Curing and Protection, and an illustration is given of a suitable type of double template for striking the surface to a contour. As stated in the foreword, special conditions met with in different localities require special treatment which must be left to the engineer in charge of the work, but the specification will be found to be a sound guide for general practice or on which to base a specification to meet special problems. The suggested specification (which is an amended form, with an addenda, of that given in " Concrete Roads ") has been approved by Mr. H. Percy Boulnois, M.Inst.C.E. (Chairman of Council of the Roads Improvement Association), and Mr. Alfred Dryland, M.Inst.C.E. (Engineer and Surveyor for the County of Middlesex), and may be obtained, free, from the Concrete Utilities Bureau, 35 Great St. Helens, E.C.3.

WHAT IS THE USE OF THE MODULAR RATIO?*

By H. KEMPTON DYSON.

The title of this paper does not properly describe its scope. It savours perhaps of the frivolous and the ostentatious, but it was chosen because it indicated shortly its purpose of throwing doubt upon the current and generally accepted theory of reinforced concrete calculations in which the so-called "modular ratio" is so fundamental a factor. Of course, the ratio of the moduli of elasticity of different materials enters into calculations as to the relations of such materials when subjected to static or dynamic forces.

The modulus of elasticity expresses the relation between stress and strain, and is the ratio thereof. The modulus of elasticity is often referred to as though it were a constant, i.e., the ratio of the stress to the strain as uniform. For almost all materials the ratio is variable.

Steel is a material which, for low stresses, seems to have almost a constant modulus, the point where there is a distinct departure being known as the elastic limit. At a slightly higher stress there is a very distinct departure, the strain increasing greatly and being largely plastic, giving a "permanent set." This is known as the "yield point."

In many practical constructions a certain amount of permanent set is always reckoned upon. In ordinary building, we are familiar with permanent set, and we feel quite confident as to the stability of the construction when it settles down to its work.

The computation of the stresses in materials subjected to permanent plastic deformation has not received sufficient attention. Elasticians (as those scientists who have made notable contributions to the mathematical theory of stresses and strains in elastic materials have been called) have simplified their mathematics by considering only ideally elastic materials —which would imply ideal conditions.

Fig. 1 shows a stress-strain diagram of a tensile test on ordinary mild steel stretched to beyond the yield point. The curve shows that when the stress is taken off the bar and the load falls to zero, there is a permanent set. The loading is now repeated. For this second time of loading the modulus (ratio of stress to strain) remains practically constant up to the limit to which the bar had first been strained. If the loading be continued beyond that point, there is again further plastic deformation, and, on the removal of the load, a similar result occurs.

It will be seen that with ordinary ductile mild steel, if we exceed the normal yield point, we may create new and higher yield points by cold working the steel, and so long as any repeated loading does not exceed the new yield point, no further permanent set is to be feared.

Concrete has no well-defined yield point, like steel; but somewhat similar phenomena are found by causing the material to undergo permanent deformation by repeated loading. By repeated loading the modulus of concrete becomes much more uniform than appears from the stress-strain curve for the first time of loading, but, nevertheless, the modulus is not constant.

Engineers have found out by experience the advisability of using mild low-carbon steel in structures as against brittle high-carbon steels. Mild steel, as a ductile material, has the virtue of not losing strength in either tension or compression, by undergoing plastic deformation. Perhaps structural engineers, as regards so-called brittle materials, are more familiar with those that have low tensile strength like concrete, stone and brick. This is not a necessary feature of a brittle material as, for example, high carbon steel which may have a high tensile strength, and yet be brittle. The brittleness merely indicates that the material is not malleable, or appreciably deformable, without loss of strength in tension. We are afraid of brittle materials in tension and in bending because the bending produces tension, but we are not so afraid of them in compression. With ordinary building materials, such as concrete, brick and stone, the general use is for compressive resistance, and we are not afraid of a good deal of deformation. The author has observed in making compression tests on concrete, as no doubt others have, that if one applies the loading at a fairly rapid rate a higher result may be obtained than if the load be applied slowly, and has further noted that if a load near the ultimate strength, determined as usually, be kept on a specimen for, say, an hour or two, rupture will take place at the lower load.

Though engineers may be afraid of brittle steel in riveted steel structures where, owing to deflection under load, uncalculated secondary stresses are put into the rigid joints, we are accustomed to using such materials for other engineering purposes. Where brittle materials have low tensile strengths compared with their compressive resistances, such as cast iron, concrete and stone, we fear to use them in tension, yet we are familiar with their use in compression. Their ability to undergo considerable plastic deformation must be a reason for their practical utility. Certainly, by re-loading, we see that it may be possible to render them as brittle in compression as tool steel. If we could use materials that had been re-loaded many times, so as to make them elastic, but having elastic limits near to their ultimate strengths,

* Abstract of a paper read before the Concrete Institute on February 23.

we should be just as afraid of using them in positions where secondary stresses might be produced as we are in the case of brittle steel in riveted structures. When, however, we use them in brick and stone buildings and in reinforced concrete structures, they are built into the work in a comparatively unstrained state, and are, therefore, able to undergo on loading a great deal of plastic deformation.

The formulæ which are ordinarily put forward as applying within the limits of elasticity may give fairly accurate data for structural steel work, and they provide practically the only method of calculating slender pillars and continuous construction, though that does not mean that they even closely approximate to really accurate results. The settlement of supports and plastic deformation must make appreciable divergences.

Bending of Homogeneous Beams.

In the ordinary theory as regards stresses in beams as set out in the usual text-books on the theory of structures, we find statements about the stresses in the fibres of a beam bent by transverse loading varying as the distance from the neutral axis, the neutral axis being the position in the beam above which the fibres are shortened by compression, and those below extended by tension.

Frequently, also, statements are made that plane sections remain plane after bending. The author's former paper on "Shear" demonstrated that, in practice, this is not so, and indeed that the assumption is never warranted. It may be an interesting graphical illustration, but seeing that it is foreign to the truth the wisdom of putting it forward to the student is doubtful. We see the same statement in books on reinforced concrete about plane sections remaining plane after bending. This is particularly aggravating when the authors go on to point out that concrete cannot be depended on in tension, as it will probably crack, and, indeed, cracks can be expected in reinforced concrete. If a crack occurs in the concrete, and not in the steel bar, obviously the plane section cannot remain plane after bending. The concrete has either slipped past the bar or the bar past the concrete.

If a material is perfectly elastic and undergoes equal strain for equal stress in tension or compression, it is evident that in a symmetrical section the neutral axis will lie in the middle. There is a neat graphical demonstration for the determination of the neutral axis in unsymmetrical sections in a book which is too little known to structural engineers, namely, *Elementary Applied Mechanics*, by Alexander and Thompson, pupils of Rankine. For students unfamiliar with the calculus their demonstration of the moment of inertia and the section modulus of a figure is one of the best. With that one has no quarrel because the authors clearly point out that it only applies on the assumption of a uniformly varying stress. We can, of course, modify such a method to suit materials having different moduli of elasticity in tension and compression, and even variable moduli, but artifice is necessary.

Another familiar mode of calculation is to employ the theorem of least work, but it still requires us to assume the distribution of strain and stress just as before. That method has been applied to reinforced concrete beams, based upon the same assumptions as the ordinary theory. The demonstration is free from the error about plane sections remaining plane, yet it depends upon the truth of the assumptions.

It is a well known fact remarked upon in many books on the "strength of materials" and "theory of structures" that ordinary rectangular sections of homogeneous material when subjected to bending develop moments of resistance at ultimate loading that are greatly in excess of what would be expected by multiplying the section modulus (derived from the moment of inertia) by the maximum tensile stress that the material is able to sustain. Or alternatively, if the ultimate moment of resistance be divided by the section modulus a maximum fibre stress is indicated far in excess of what can be ascertained by pure tensile tests Sir Benjamin Baker remarked upon this in his book published in 1870, and gave the value for cast iron rectangles as being apparently 2·25 times the ordinary tensile stress, or put in another way the ultimate resistance moment was $2\frac{1}{4}$ times as much as was expected from theory. For wrought iron the corresponding value that he obtained was 1·57. The reason is that in the final stages of loading the outer fibres become overstrained, with the result that the material begins to deform plastically, thus throwing gradually more and more on the inner fibres.

The successive stages of stress distribution for a symmetrical section of a material with equal tensile and compressive functions are shown in *Fig.* 2, and for materials having a tensile strength less than the compressive in *Fig.* 3. If we assume the ultimate stress figure to be something in the nature of a quarter ellipse we can determine the centres of gravity of the stresses—i.e., the centres of pressure and tension—the arm between and the amounts of total tension and total compression.

Now let us consider a simple little demonstration of the fundamental mechanics of a beam. *Fig.* 4 illustrates a cantilever projecting from a wall and carrying a weight $\frac{W}{2}$ at the

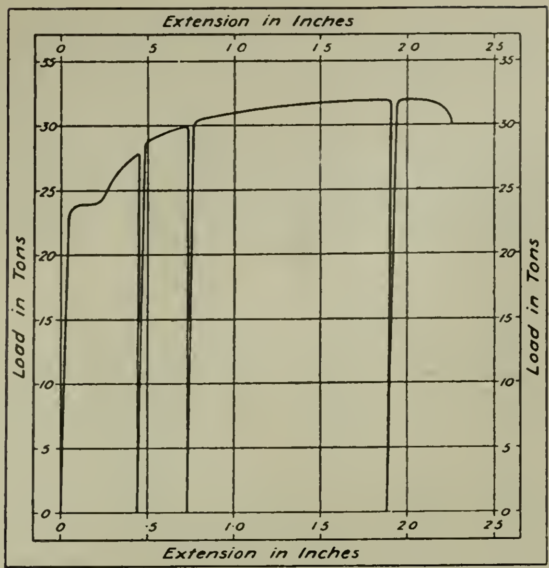


Fig. 1. Stress Strain Diagram of a Steel Bar.

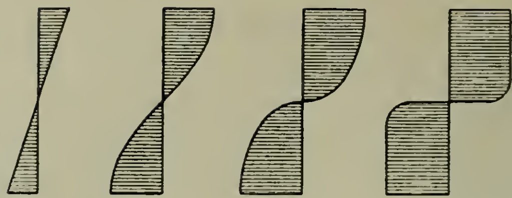


Fig. 2.

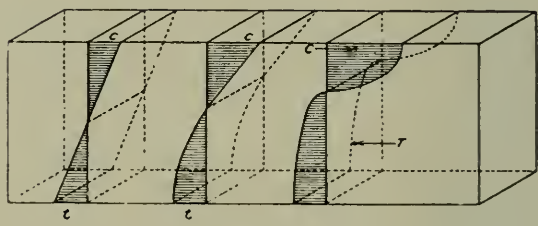


Fig. 3.

end, distant a length $\frac{l}{2}$ from the support. *Fig.* 6 shows a beam carrying a load W about the middle of the span l. The reaction at each end is obviously $\frac{W}{2}$. If the figure be reversed it will be evident that the conditions of each half are similar to those of the cantilever, bending taking place about the centre. The load or reaction amounting to $\frac{W}{2}$ is in each case acting with a leverage $\frac{l}{2}$. The weight multiplied by the leverage gives a moment tending to cause bending, known generally therefore as the bending moment, equal in this case to $\frac{W}{2} \times \frac{l}{2} = \frac{Wl}{4}$. Reverting to the simple case of the cantilever shown in *Fig.* 4, let us imagine that the portion beyond the dotted line is separated from the support as shown in *Fig.* 5. This body is subjected to the application of a force at one end of $\frac{W}{2}$, which tends to cause motion of translation. As the body is in equilibrium this force of $\frac{W}{2}$ must evidently be resisted by some force applied at the cut section where it was attached to the support. This equal and opposing force is the shear, symbolised by the letter S, as indicated in *Fig.* 5. But the application of two equal and opposite parallel forces upon a body tends to cause rotation. This rotation must evidently be resisted by a force or forces applied from the adjoining piece of the beam at the cut section. One force, however, is insufficient to produce equilibrium, because alone it would merely cause motion of translation, which could only be stopped by the application of an equal and opposite force. These forces are indicated in the diagram by the letters T and C, representing tension and compression. They in turn form a couple, which tend to cause rotation, the direction of rotation, however, being opposite to that of the first couple, which consist of the load and the shear. Taking moments about any point, the first couple give an amount of $\frac{W}{2} \times \frac{l}{2}$. This is the bending moment before referred to. As regards the other couple of forces of C and T, representing total compression and total tension, acting at a distance apart equal to a, the leverage arm of the couple, taking moments for this couple of equal and opposite forces about any point (similar to what we have done for the first couple), we find that the moment is Ta or Ca, these being equal, because $C = T$. This moment resists the moment of the other forces, and is known as the resistance moment. In short, the resistance moment is equal to the bending moment, and the total compression equals the total tension.

In the case of materials that are weaker in tension than in compression, at first the neutral axis will lie at the centre of the section, as at the left of *Fig.* 3. As the weak tension side is overstrained and the inner fibres become stressed more nearly to the outer fibres, the neutral axis will move upwards so as to make the volumes of the tension and compression stress

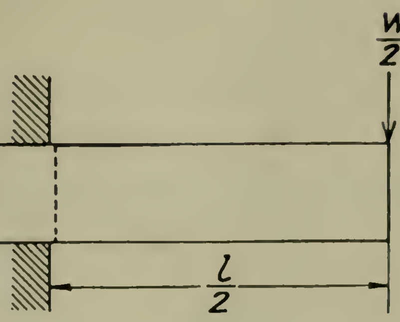


Fig. 4.

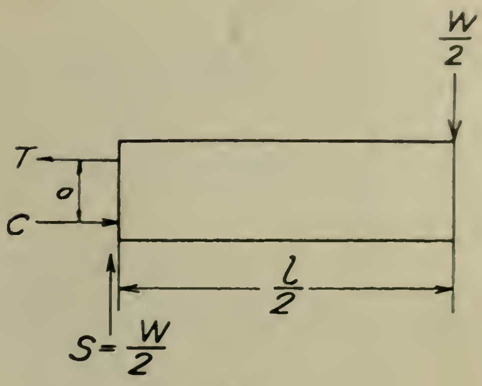


Fig. 5.

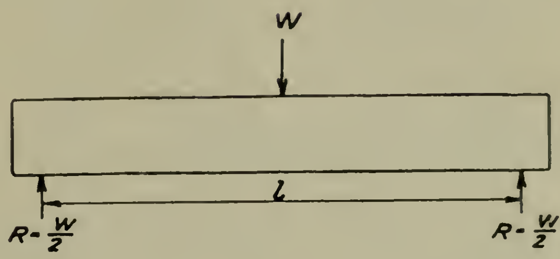


Fig. 6.

figures equal. If, of course, the conditions were reversed, by the material being stronger in tension than in compression, the neutral axis would by the same argument have to travel downwards. However, in the present case with cast iron or concrete, as the neutral axis travels upwards the outer fibre stress in compression becomes gradually increased, while more and more is brought into play in tension, until finally the area in compression becomes so small that the ultimate compressive resistance of the material is reached, when by plastic deformation the inner fibres become more uniformly stressed. By such argument both ultimate stresses are reached at the same time. Assuming elliptical stress distribution as before we can calculate the ultimate resistance moments if we know the ultimate tensile and compressive stresses.

Referring to *Fig.* 3, let

$$f\,max = N.f\,min$$

$$\because C = T$$

$$\therefore \cdot 7854 b.f\,max.n = \cdot 7854 b.f\,min\,(d - n)$$

$$\text{Also } f\,max.n = f\,min\,(d - n)$$

$$\therefore n = \frac{f\,min}{f\,max + f\,min} d$$

$$a = d - \cdot 4244\,n - \cdot 4244\,(d - n) = \cdot 5756\,d$$

$$R_u = \cdot 7854 \times \cdot 5756 \,.\, \frac{N.f\,min^2}{f\,min\,(N + 1)} \,.\, bd^2$$

$$= \cdot 452 \frac{N.f\,min}{(N + 1)} \cdot bd^2$$

$$\text{Ordinary Elastic } R_e = f\,min \frac{bd^2}{6} = \cdot 166\,f\,min.\,bd^2$$

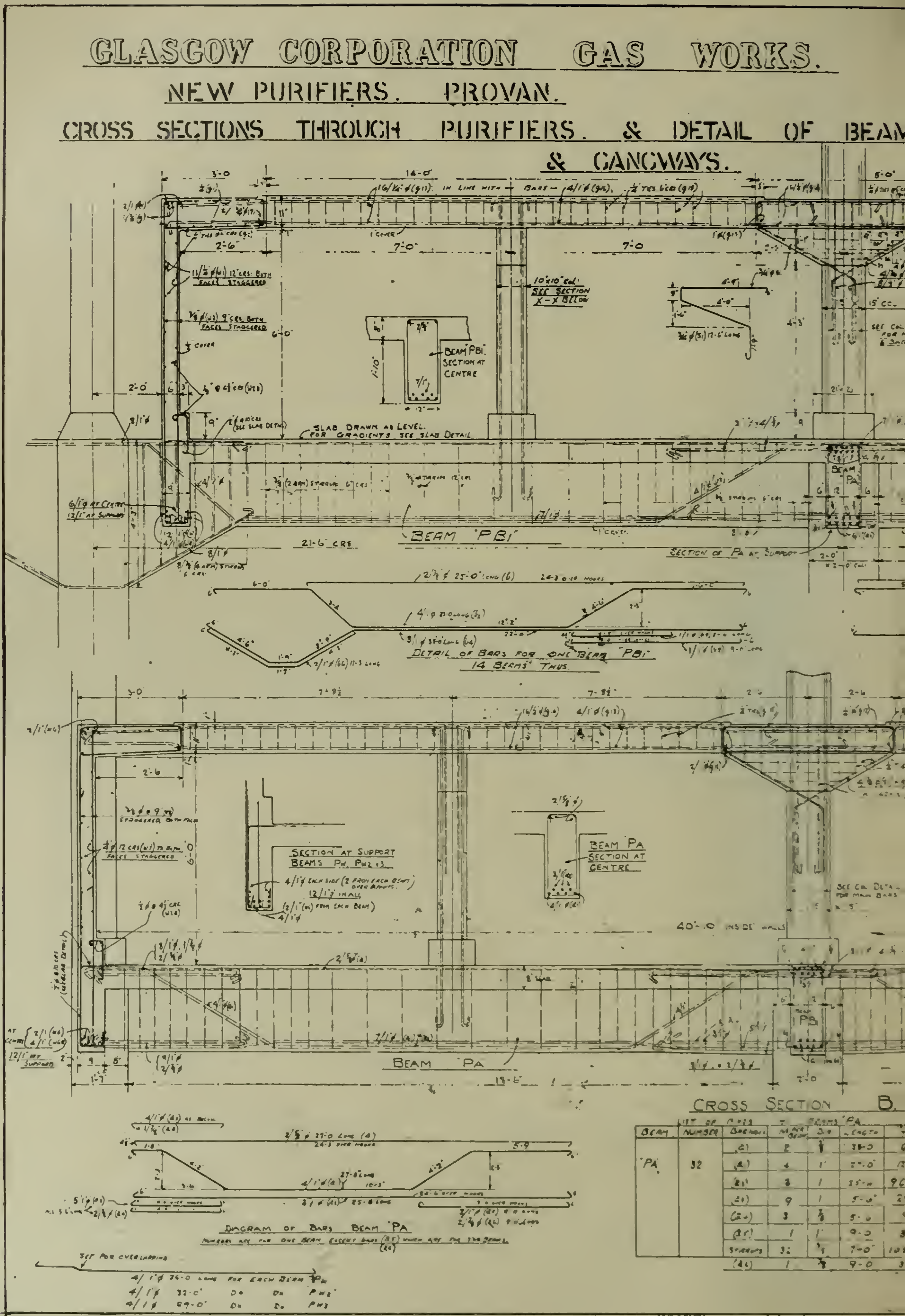
For $N = 4 \quad R_u/R_e = 2{\cdot}17$

For $N = 1{\cdot}3 \quad R_u/R_e = 1{\cdot}53$

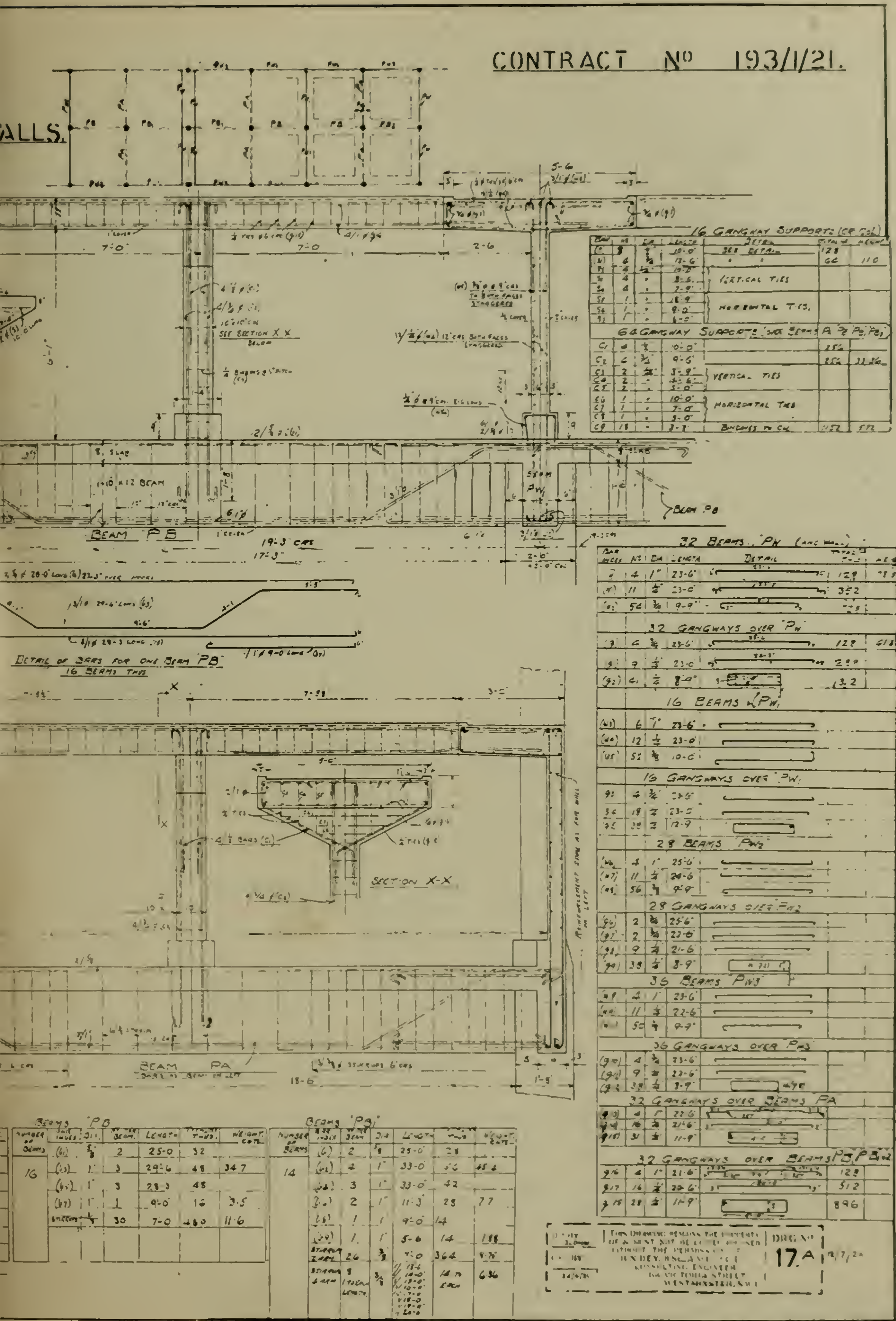
On the basis that the tensile strength of cast iron is roughly about ¼ of the compressive resistance, we obtain the ratio of ultimate to elastic resistance moments as 2·17, which is near the value 2·25 given above, while for wrought iron with tensile strength 1·3 times the compressive strength we get 1·53 as against 1·57 above. This is close agreement with experiment.

Such a theory is extremely simple if we once assume the shape of the stress figure at the

(*Continued on p.* 336.)


GLASGOW CORPORATION GAS WORKS.
NEW PURIFIERS. PROVAN.
CROSS SECTIONS THROUGH PURIFIERS. & DETAIL OF BEAM
& GANGWAYS.
BEAM "PB1"
DETAIL OF BARS FOR ONE BEAM "PB1"
14 BEAMS THUS.
BEAM PA
SECTION AT CENTRE
SECTION AT SUPPORT
BEAM "PA"
CROSS SECTION B
DIAGRAM OF BARS BEAM "PA"

PROVAN GA


CONTRACT No 193/1/21.
ALLS.
16 GANGWAY SUPPORTS
64 GANGWAY SUPPORTS
VERTICAL TIES
HORIZONTAL TIES
BEAM PB
DETAIL OF BARS FOR ONE BEAM PB
16 BEAMS THUS
32 BEAMS PW
32 GANGWAYS OVER PW
16 BEAMS PW1
16 GANGWAYS OVER PW1
28 BEAMS PW2
28 GANGWAYS OVER PW2
36 BEAMS PW3
36 GANGWAYS OVER PW3
32 GANGWAYS OVER BEAMS PA
SECTION X-X
BEAM PA
BEAMS PB
BEAMS PB1
DRG No 17A

s (see p. 296.)

(*Continued from p.* 333.)

ultimate. The only thing we need is a fairly close approximation to the true stress distribution. If much squeezing goes on by plastic deformation of the fibres the stress figure may become almost a rectangle or something like the right-hand diagram of *Fig.* 2. For concrete it has been suggested by various experimentalists that the stress-strain curves for concrete in compression indicate that a parabola would be justified, merely having regard to the varying modulus of elasticity of the concrete, but the author would prefer to adopt an ellipse as being justified by the known squeezing of the outer fibres ; that gives a figure more approaching the rectangle than does the parabola, while, on the other hand, it must be fairly evident that a complete rectangle cannot be justified. The ellipse is a figure that is somewhere between the two, with simple known properties.

Referring to *Fig.* 3, as applicable to concrete or cast iron, requiring merely a modification to suit the particular properties of each material, we see that at first when the material is fairly elastic the neutral axis will be at the centroid of the cross-section, because the strain will vary directly as the distance from such axis, and likewise the stress. The material being weaker in tension than in compression, the ultimate tensile strength will evidently be reached at an early stage of continued loading. As soon as that stress is reached, stretching must occur, i.e., plastic deformation. As a result the neutral axis will move upwards, the strain will no longer be directly proportional to the distance from such axis, and the stress will become somewhat as sketched in the second part of the diagram. The succeeding stage is likewise indicated. Such considerations would indicate that unless the material has some power of recovery, plastic deformation under repeated loading will become more and more, until no further give is possible. Seeing that the inner fibres are not so greatly strained as the outer fibres, the deformation in them is probably more elastic, or, to put it another way, the plastic deformation in such fibres will be less. The effect of this will be that on removal of the load these inner fibres will tend to recover themselves more than the outer fibres, and will help to push the latter back into their original condition. This can be noticed in certain materials by a gradual creeping back of deflected beams, so that they become straighter after a period of rest than they were on first removal of the loads after overstrain.

By repeated plastic deformation materials, as we have seen, become nearly perfectly elastic, but at the same time brittle. Each time of reloading, therefore, the neutral axis will start at the middle, and subsequently the tension side will be overstrained and more plastic deformation produced. The result must be eventual cracking and rupture on the tension side. This is somewhat allied to the effect of failure by impact or by fatigue.

(*To be continued.*)

CONCRETE AGGREGATES.—(*continued.*)

Norfolk—(Beetley).

(1) *General description :* Red gravel, deep seam, very good stones.
(2) *Source and locality of same :* Beetley Pit, Beetley.
(3) *How obtained :* Manual labour.
(4) *From whom obtained :* Mr. R. S. Butcher, Estate Agent, Fakenham.
(5) *Is available quantity limited ? If so how ?*—Unlimited.
(6) *Present maximum output per day (stated in cubic yards) :* No record.
(7) *Transport facilities :* Engine or team labour.
(8) *Is there any provision at or near source for washing or crushing ?* No.
(9) *Price per cubic yard, and where delivered :* 1s. per load royalty in pit.
(10) *Is composition uniform ?* Yes.
(11) *Detailed description :*—
  (*a*) *Kind of stone or coarse material :* One-third of ¾ in., one-third 2 in., one-third 4 in.
  (*b*) *Kind of sand or fine material :* Gritty, fine, sandy gravel, much shingle.
  (*d*) *Shape of particles (rounded, angular, flat, etc.) :* Inclined to be round ; irregular.
  (*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* Small and large stones only bedded in red gravel.
(12) *Is sample sent with this sheet ?* No.

Norfolk—(Brook).

(1) *General description :* Sound gravel suitable for concrete work.
(2) *Source and locality of same :* Gravel pit.
(3) *How obtained :* Manual labour.

(4) *From whom obtained?* Mr. Cook, Brook Hall, Brook, Norwich.
(5) *Is available quantity limited? If so, how?* No.
(6) *Present maximum output per day (stated in cubic yards):* 10 yds. (two men working pit).
(7) *Transport facilities:* Team labour only.
(8) *Is there any provision at or near source for washing or crushing?* No.
(9) *Price per cubic yard, and where delivered:* 5*s.* 6*d.* per cu. yd. in pit.
(10) *Is composition uniform?* No.
(11) *Detailed description:—*
  (*a*) *Kind of stone or coarse material:* Gravel from ½ in. to 4 in.
  (*b*) *Kind of sand or fine material:* No sand in this pit—good sand pit near by.
  (*c*) *Relative proportions of coarse and fine material:* ¼ fine, ¾ coarse.
  (*d*) *Shape of particles (rounded, angular, flat, etc.):* More or less rounded.
  (*e*) *Size of particles; approximate percentage that needs crushing to pass ¾ in. screen:* About ⅝ of each yd.
  (*f*) *Impurities present (as clay, sulphur, coal, organic matter):* About 3 cu. ft. of soil to each yd.
(12) *Is sample sent with this sheet?* No.

Norfolk—(Broome).

(1) *General description:* Clean sound gravel suitable for concrete work.
(2) *Source and locality of same:* Gravel pit, Broome.
(3) *How obtained:* Manual labour (no plant).
(4) *From whom obtained?* Mr. W. W. Mickleburgh.
(5) *Is available quantity limited? If so, how:* Yes, to one field (3 acres).
(6) *Present maximum output per day (stated in cubic yards):* 10 yds.
(7) *Transport facilities:* Team labour (station, 1 mile).
(8) *Is there any provision at or near source for washing or crushing?* No.
(9) *Price per cubic yard, and where delivered:* 7*s.* in pit.
(10) *Is composition uniform?* No.
(11) *Detailed description:—*
  (*a*) *Kind of stone or coarse material:* Gravel from ½ in. to 3 in.
  (*b*) *Kind of sand or fine material:* No sand; good fine shingle.
  (*c*) *Relative proportions of coarse and fine material:* One-third fine and two-thirds coarse material.
  (*d*) *Shape of particles (rounded, angular, flat, etc.):* Larger stones more or less rounded, remainder angular.
  (*e*) *Size of particles; approximate percentage that needs crushing to pass ¾ in. screen:* About ⅔ of each yd. soil.
  (*f*) *Impurities present (as clay, sulphur, coal, organic matter):* About 2 cu. ft. in each yd.
(12) *Is sample sent with this sheet?* No.

Norfolk—(Eccles).

(1) *General description:* Gravel flints.
(2) *Source and locality of same:* Eccles pit, Eccles.
(3) *How obtained:* Manual labour.
(4) *From whom obtained?* Estate of the Earl of Albemarle.
(5) *Is available quantity limited? If so, how?* Extent of layer of stone not tested; depth of face, 6 ft.; acreage, 5.
(6) *Present maximum output per day (stated in cubic yards):* 10 yds. per day.
(7) *Transport facilities:* Road haulage.
(8) *Is there any provision at or near source for washing or crushing?* No.
(9) *Price per cubic yard, and where delivered:* 5*s.* per yd. in pit.
(10) *Is composition uniform?* Yes.
(11) *Detailed description:—*
  (*a*) *Kind of stone or coarse material:* Blue and grey flints.
  (*b*) *Kind of sand or fine material:* Very small percentage of building sand.
  (*c*) *Relative proportions of coarse and fine material:* 1 of coarse to 5 of fine.

EXPERIMENTAL COTTAGES AT AMESBURY.

An account of some of the buildings erected at Amesbury by the Department of Scientific and Industrial Research has already appeared in these columns, and the Department has now issued a very full report * of all its work, which should be read by those who are interested in developing new or reviving old methods of cottage architecture. The reader of this report will at once be struck by the thoroughness which characterises all the work in connection with the five cottages with which the report deals, and with the minute attention given to detail.

The five cottages described in this report are built of ordinary brickwork, monolithic concrete, chalk and cement, chalk and straw, and chalk-*pisé* (chalk and soil). The concrete cottage is built with a solid wall 12 in. thick to the first floor and 9 in. above. Illustrations showing a section through the walls and the form of shuttering which was employed are here reproduced (*Figs.* 2, 3, and 4). This shuttering, which would seem to be at once simple and efficient, was also used for the chalk and the *pisé* cottages. The mixture was composed of one of Portland cement to eight of clean Amesbury gravel. To prevent temperature and angle cracks, vertical strips of "Exmet" mesh reinforcement were embedded. As the temperature conductivity of a monolithic concrete wall with solid aggregate is extremely high, it is to be anticipated that the solid wall

* *Experimental Cottages.* A report on the work of the Department of Scientific and Industrial Research at Amesbury. By W. R. Jaggard, F.R.I.B.A. (London: H.M. Stationery Office.) Price 5s. net.

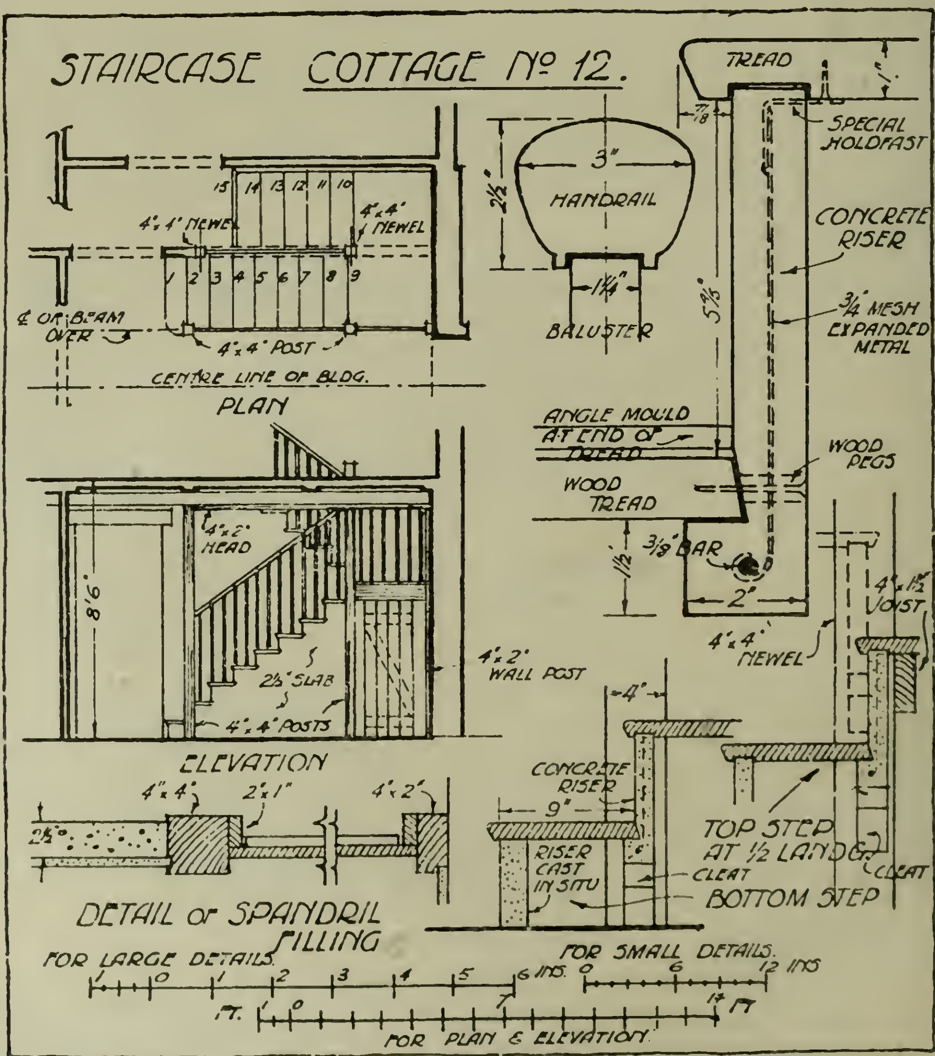


Fig. 1.

will be subject to the condensation of moisture on its inner surface, and that the building will be hot in summer and cold in winter. It would be interesting to ascertain the views of the inhabitants. The opportunity might have been taken to test the American system of forming a cavity between the solid monolithic wall and an internal lining of plaster on expanded metal or wooden lathing, or of composition boarding. This is a simpler method of forming a cavity with a monolithic wall than the usual English practice of making the wall of two thicknesses of

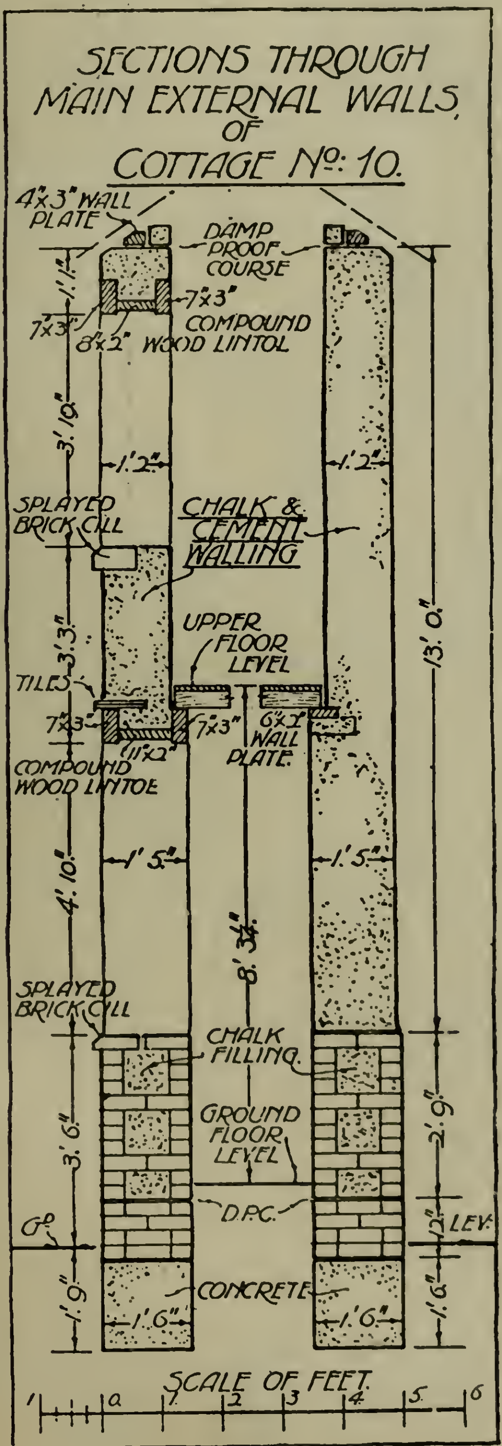


Fig. 2

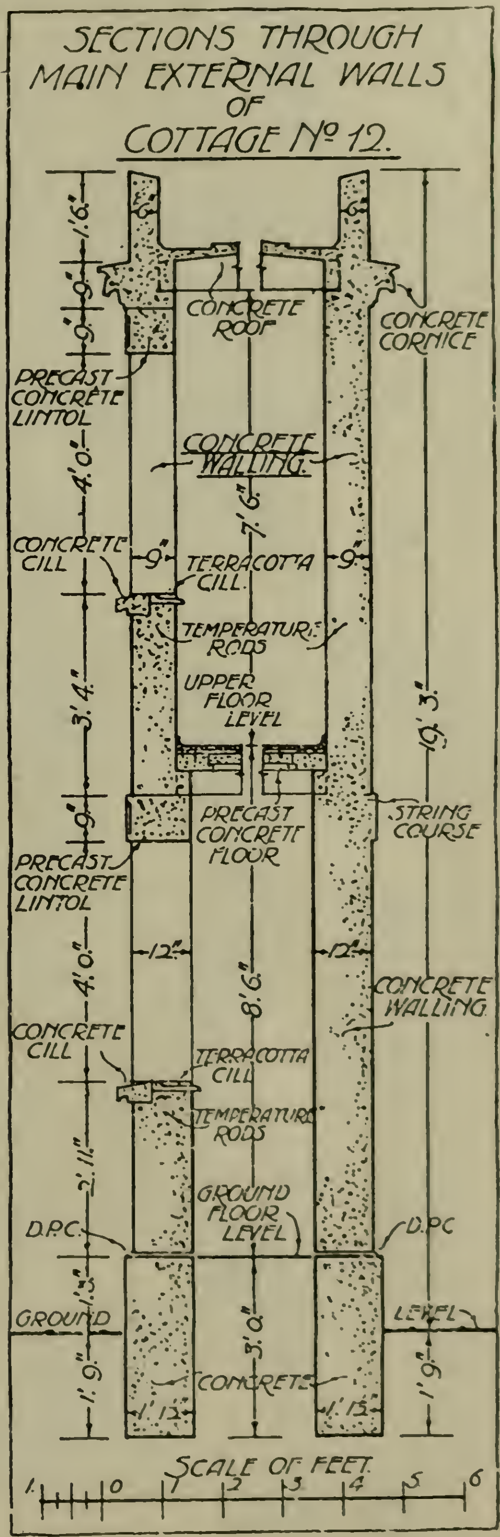


Fig. 3

concrete, for which a complicated shuttering is often used. The first floor of this house is formed of pre-cast units consisting of **T**-beams and slabs.

The specification for the chalk and cement walls is as follows : " The chalk, after digging, will be broken to pass a $1\frac{1}{2}$-in. mesh. It will then be mixed dry, on a boarded platform, with one-twentieth of its weight of Portland cement, by

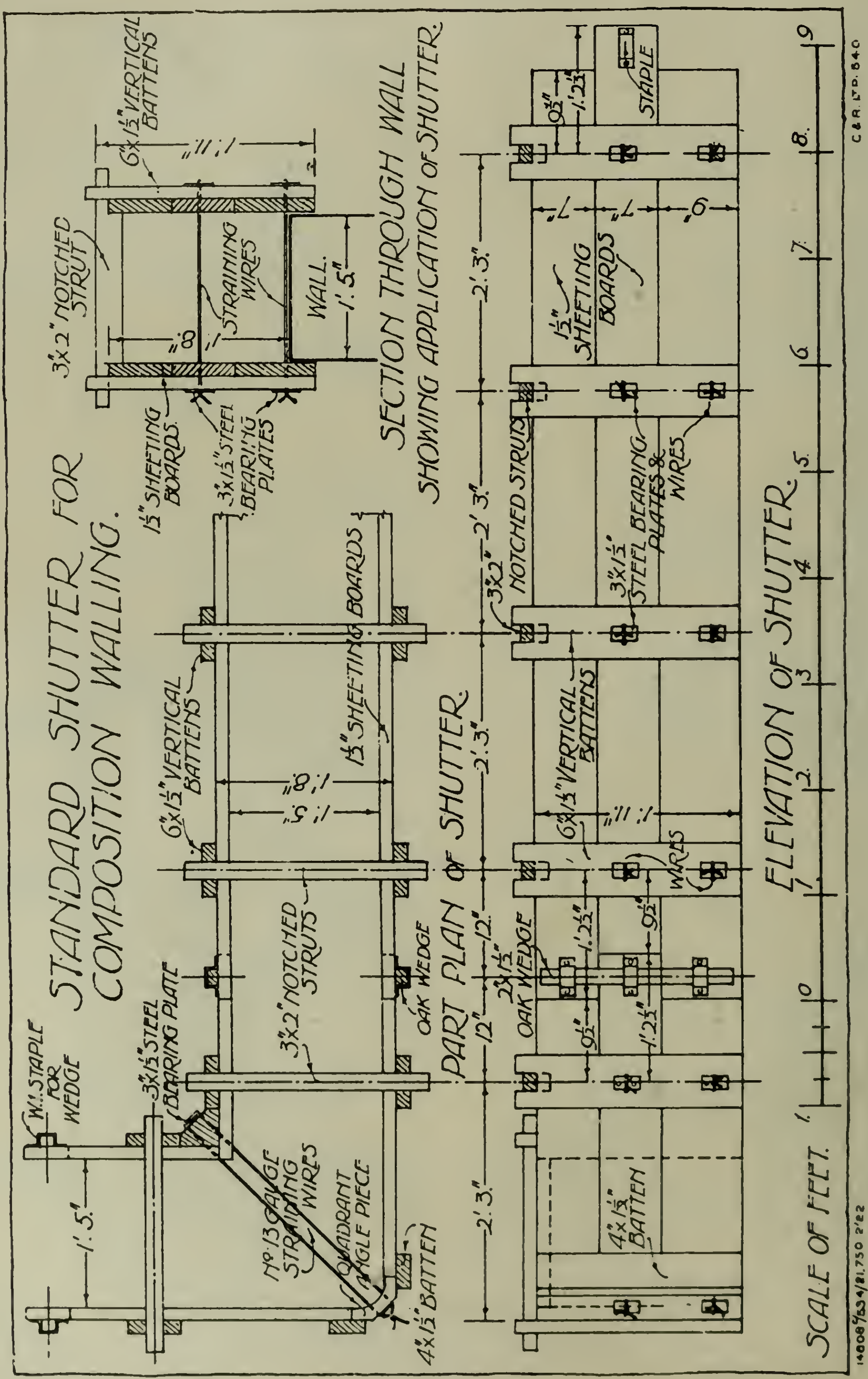


Fig. 4.

turning over at least three times, as in concrete mixing, and none of the mixture must be allowed to stand for more than thirty minutes before using." No water was added. The external walls are 1 ft. 5 in. thick up to the first floor, above which they are 1 ft. 2 in. thick.

The arrangements for cooking, heating, and supplying hot water, which differ in each house, are interesting, as in some of the individual cottages systems of central heating have been installed. It is to be hoped that a further report, as is suggested, will be published by the Department, dealing with these various systems, and showing how they compare in fuel economy, cleanliness and efficiency and how they appeal to the class of tenant for whom they are intended. Indeed, a further report dealing with the buildings from every aspect after they have been lived in for a year or two and weathered a couple of winters would be of real interest and of service to all connected with housing.

It is impossible to do justice to the fulness and thoroughness of this report in a short notice. Every item is considered, and there are large scale drawings of all joinery and other details, which are of immense interest and value, together with a number of photographs of the cottages, both within and without, both during construction and after completion.

The Department, which was fortunate in having the services of Mr. Jaggard, is to be congratulated upon its work, and upon the very valuable report that it has produced. If we have a criticism to make, it is that an index should have been included.

CORRESPONDENCE.

Reinforced Concrete Roads.

SIR,—The letter from Mr. Peggs in your March issue in regard to the standardisation of reinforced road construction will be much appreciated as a suggestion to put this important matter on a regularised footing. At the same time one can hardly withhold the opinion that such standardisation at the present stage would be a great mistake. The construction is too young to attempt to standardise it officially. We all know that official standards are more easily made than altered, and it would seem much better at the present stage to leave the construction to develop in the ordinary way until it becomes more or less standardised unofficially.

A considerably greater amount of this construction has been carried out in the U.S.A. than here, and we might take a hint from their experience. At the Road Congress last but one a definite specification was suggested, for instance, for the amount of reinforcement, and at the following Road Congress, i.e., the most recent Congress, this recommendation was withdrawn, and it was suggested that the matter should be left open for the time being. The B.R.C. specification, which is based both on American practice and on long experience in this country, is here more or less adopted as standard, and has given sufficiently good results over a number of years to show that it does not in the main require alteration.

I think Mr. Peggs is incorrect in his statement about reinforcement. The method followed in this country has been quite contrary to the American method. The American method is to reinforce transversely with the reinforcement at the top, and to use expansion joints. The English method has been to reinforce longitudinally with the reinforcement at the bottom and to omit expansion (or contraction) joints. In laying transverse reinforcement the American practice of putting it near the top is correct, because transverse reinforcement at the bottom of the slab is uneconomical. On the other hand, when expansion joints are omitted the reinforcement should be mainly longitudinal and laid near the bottom of the concrete. This is the arrangement which has so far been used here to the greatest extent, and no case has yet appeared to show that it does not give the most satisfactory results, both in regard to spreading the load and in regard to reducing contraction cracks.

J. F. BUTLER,
Managing Director.

British Reinforced Concrete Engineering Co., Ltd.

CEMENT NOTES.

By Our Special Contributor.

White Cement.

WHITE Portland cement is in occasional demand in this country for architectural and decorative purposes, and if the price were lower it is probable the demand would grow. There is no white Portland cement made in the United Kingdom, and the small British requirements are met by imports from the United States, thus accounting for the high price, which includes carriage from the American works to the coast, shipment to English port and storage charges in this country.

White cement differs from ordinary cement only in the proportion of iron oxide it contains, as it is this constituent that gives Portland cement its characteristic grey colour. In white cement the proportion of iron oxide is less than 1 per cent. compared with an average 3 per cent. in the ordinary material. This freedom from iron oxide is obtained by the use of raw materials containing little or none of that constituent, such as, for example, pure limestone and china clay, and in the process of manufacture it is necessary to avoid contamination with iron, especially in the kiln, where oil or specially selected coal must be employed for calcination.

There is no reason why white cement should not be made in England, although the cost of production would be high, because pure limestone or chalk does not occur in the same district as china clay, and heavy carriage charges would be incurred in bringing the two raw materials together, while coal of the necessary quality, or oil, would cost more than the fuel ordinarily used for cement burning. Finally, the small demand for white cement implies a small output, which would also tend to high cost. Unless, therefore, the demand for white cement should show any indications of reaching say 25,000 tons per annum, there is no inducement for a British cement manufacturer to undertake its production.

A moderately good imitation of white cement is obtained by choosing a naturally light-coloured Portland cement and mixing it with barium sulphate (barytes) in the proportion of 2 parts cement to 1 part barytes, and in some cases this mixture has produced a shade quite light enough to secure the decorative purpose.

The Density of Concrete.

The materials composing concrete, viz., hydrated cement, sand and gravel or stone have an average density of about 2·5, and it follows that a concrete of maximum density, i.e., perfectly free from voids, would have a weight per cubic foot of 2·5 × 62·4 lb. = 156 lb. It is to be doubted whether in practice concrete reaches within 10 per cent. of this weight, viz., 140 lb. per cubic foot, thus implying 10 per cent. of voids, which rob the concrete of its strength and impermeability.

It is or should be the aim of all producers of concrete to achieve density, and this is done by several means, notably by using the minimum of water with the concrete and then tamping or puddling to consolidate, by applying hydraulic pressure as in machine slab-making, by vibration or "jigging" the concrete or by rotation so that centrifugal force comes into play.

The value of "puddling" or "rodding" concrete has previously been referred to in these notes, and one example will be sufficient to illustrate the additional strength obtained by pushing a ⅝-in. rod into a cylindrical concrete test piece (12 in. by 6 in. diam.) about twenty-five times and repeating the operation five times at intervals, allowing surplus water to escape.

	Compressive Strength. lb. per sq. in.	Weight per cu. ft. in lb.
Rodding once . . .	2,208	147·5
Rodding six times . .	3,181	150·7

These tests are representative of fifty similar tests with varying mixes and consistencies reported by Giesecke to the American Society of Testing Materials.

Under certain conditions of reinforcement, "rodding" may not be practicable, and then tamping can take its place with the same effect, as shown by Abrams (Bulletin 3, Structural Materials

Research Laboratory, Lewis Institute, Chicago), as follows :—

	Compressive strength lb. per sq. in.
Rodding. 25 strokes with ⅝-in. rod for each 4 in. layer in cylindrical concrete test piece (12 in. by 6 in. diam.)	2,780
Tamping. 25 strokes with 2 lb. 2 in. tamper for each 4 in. layer as above	2,800

By the application of pressure to concrete it is possible to work with a dry mix, which of course tends to increased strength, but also, with sufficient pressure, it is possible to expel water from the concrete with a gain in strength. The following examples of the effect of pressure upon the strength of concrete are quoted from Abrams (*loc. cit.*) :—

				Compressive strength lb. per sq. in.
Rodded concrete				2,780
Do. plus pressure of 2 lb. per sq.in.				3,000
Do.	do.	50	do.	3,140
Do.	do.	100	do.	3,320
Do.	do.	200	do.	3,480
Do.	do.	500	do.	3,540

Abrams observed that the gain in strength is proportional to the quantity of water expelled, and consequently there s no advantage in maintaining the pressure after water ceases to flow from the concrete.

The vibration or "jigging" of concrete during moulding is only advantageous to strength when dry mixes are used which are difficult to consolidate by hand methods alone, but with a concrete of normal consistency Abrams' experiments show that "jigged" concrete is no stronger than rodded concrete. One attraction of concrete goods moulded on a vibrating table is, however, that the laitance is brought to the upper surface of the concrete during moulding, leaving the lower surface next to the table quite free from this source of weakness and discoloration; this lower surface can be made the exposed or wearing surface of the concrete in practice.

In connection with the consolidation of concrete by centrifugal force, it is claimed that by rotation of a hand moulded cylinder of 12 in. diameter it is possible to concentrate the concrete so that a hollow central cone of 3½ in. diameter is formed. This implies a reduction in the volume of the concrete of 8½ per cent., equivalent to an increase of about 12 lb. per cub. ft. in weight. During the process of consolidation both air voids and excess water are eliminated so that a dense, strong and impermeable concrete is produced.

Reinforced Concrete Bridge in Australia.—Work has commenced on the construction of a reinforced concrete bridge over the River Yarra, at Prahran. The architects

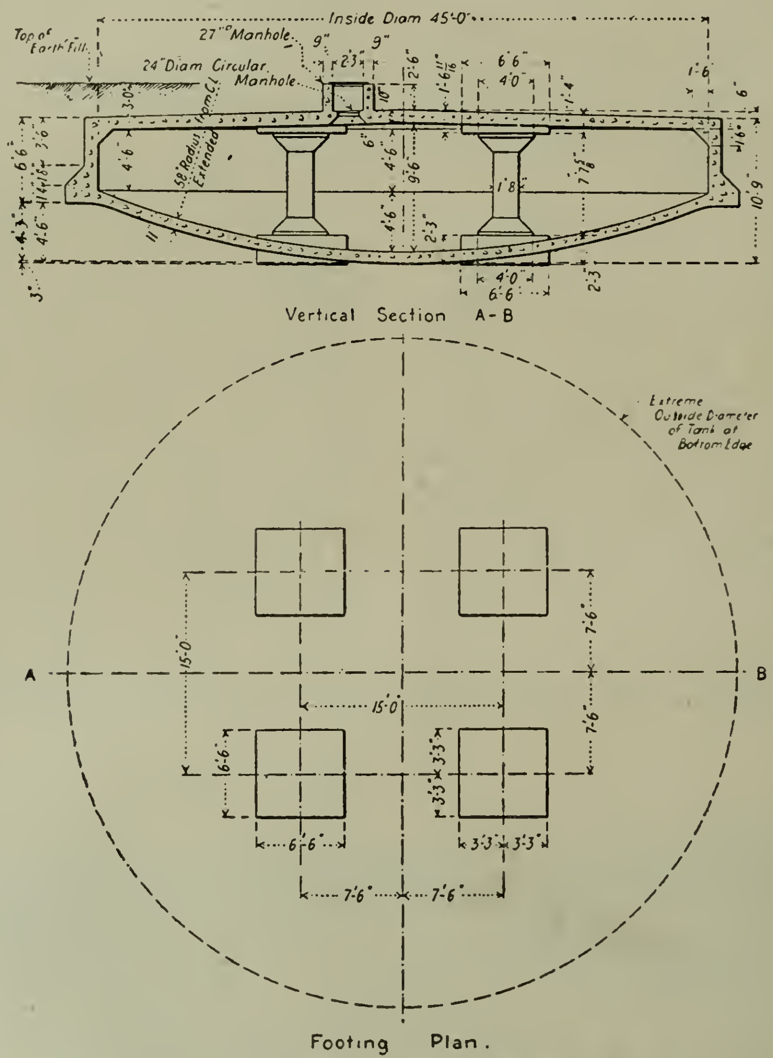
Proposed Reinforced Concrete Bridge at Yarra.

and engineers are Messrs. Desbrowe, Annear, Ashworth and J. A. Laing, and the tender of the Reinforced Concrete and Monier Pipe Construction Co. has been accepted at £68,519. It is expected that the bridge will be completed by July, 1923.

CONCRETE OIL TANKS.

THE great developments in the use of oil fuel for ship propulsion, road transport, and numerous other purposes, indicate that there will be in the near future a considerable demand for oil storage tanks, and although many tanks have been built in concrete for the purpose in this country, and proved successful, some notes on the experience gained in America in this direction will not be out of place at the present time.

In a paper read before a recent convention of the American Concrete Institute, Messrs. Pearson and Smith gave the results of some extensive investigations, which showed that samples of practically every description of mineral oil fuel had been stored in concrete tanks for a period of thirteen months without in the slightest degree



75,000 GALLON CONCRETE TANK AT MALDON, MASS.

injuring the concrete, and test cylinders which had been stored in the oils for the same period showed no appreciable diminution in compressive strength. A number of vegetable and animal oils were stored in concrete tanks for the same period, and only two—cocoanut oil and lard oil—appreciably affected the concrete. These tests also demonstrated that medium and heavy fuel oils could be stored in concrete tanks under a pressure head of 25 ft. without excessive loss, although for kerosenes, gasolines, and light oils, an impervious coating to the inner face of the tank is recommended. It was found that spar varnish was very suitable for this purpose, and a 40-degree kerosene of 0·015 viscosity was stored in a tank coated with spar varnish for a period of six months with negligible loss.

The Committee on Storage Tanks of the American Concrete Institute reports that the construction of such tanks should be limited to three continuous operations in placing: (*a*) the floor and footings; (*b*) wall and columns; (*c*) roof. The capacity limit under ordinary conditions is put at 200,000 gallons, and circular tanks are considered better able to resist induced stresses than those of other shapes. Inverted dome bottoms are recommended as giving additional storage capacity at very slight increase of cost, lessening the height of the wall, allowing better drainage, and being better able to resist upward external pressure. An efficient joint between the floor and wall is, of course, necessary, and this may be provided by forming a recess in the floor to take the wall when poured. In this recess a galvanised-iron strip, about 8 inches wide, soldered and riveted, should be placed to provide a continuous band on one side of the recess.

The Construction Division of the United States Army did not use any oil-proof coating for tanks designed for the storage of heavy oils, but for gasoline tanks the entire interior surface of the bottom, walls, and columns was sprayed with a coat of best "long-oil" spar varnish thinned with 20 per cent. of volatile mineral spirits and applied under a pressure of 60 lb. per square inch by a paint gun. After 24 hours, a coat of pure undiluted spar varnish was applied in the same manner, and after a further 48 hours this operation was repeated. One gallon of varnish was used to cover approximately 200 square feet of surface at each operation. The volatile mineral spirit used was hydrocarbon distillate, water white, neutral, clear, and free from water, which should have no darkening effect when mixed with basic carbonate white lead. Diluted silicate of soda applied in four coats has also been found satisfactory for this purpose, although it is not permanent.

The plan and section illustrated are taken from the *American Architect*, and show a 75,000 gallon tank, 45 ft. internal diameter, constructed at Maldon, Mass., by the Hallett-Grant Construction Company. The construction of two of these tanks was commenced on November 1, 1919, and completed on January 7, 1920.

TANK-WAGONS OF CONCRETE.

The first tank-wagon to be built of concrete appears to have been constructed by the Société Technique et Industrielle d'Enterprises of Paris in 1919. It is used for the transport of petroleum, weighs 25 tons, holds 15 tons and is built for rough use; the distance between the axles is 10 ft. These wagons have been subjected to various shocks whilst in use, but have endured this treatment remarkably well.

Early in the present year the same firm built a considerable number of similar wagons, but weighing only 16 tons with a capacity of 16½ tons and with a wheel-base only 9 ft. long. Still lighter wagons are now in course of construction.—*Beton und Eisen*, 1921, pp. 69, 70.

BOOK REVIEW.

Fire Prevention and Fire Protection as applied to Building Construction. By Joseph Kendall Freitag. Second Edition, Revised.

Chapman & Hall, Ltd. 1,038 pp. Price 30s. net.

"Every fire teaches some lesson ; every great fire some great lesson" is the text on which the author bases a comprehensive treatise on fire prevention and fire protection. His lessons are drawn from American experience, and he has a vast and fruitful field from which to glean conclusions, because annual fire losses in the U.S.A. are stated to approach $300,000,000, and to be nearly ten times as great per head of population as in European countries. Doubtless the extensive use of timber for building construction accounts for much of America's excessive fire loss, but this has not by any means limited fire experience to timber, because in the great conflagrations at San Francisco (after the earthquake), Chicago and Baltimore many concrete and other substantial buildings were the subject of external attack by fire.

The book deals in systematic fashion with fire insurance statistics and theory, the fire-resistance of materials, the design of fire-resisting buildings and the application of fire-fighting apparatus. Several great fires are studied in detail and the often conflicting evidence and opinions thereon are summarised in the effort to draw impartial conclusions. For English engineers, the work has its limitations because American building methods and specialist systems are frequently not those adopted in this country, and it is only in the extracts from the British Fire Prevention Committee's Red Books that English specialities are referred to, but this does not detract from the value of the book as a survey of the principles of building construction in relation to fire resistance.

So far as fire-resisting materials are concerned, the author has arrived at the conclusion that concrete and terra-cotta are the most to be preferred, and that there is little to choose between these two. Seeing that terra-cotta is essentially a protective medium and almost negligible as a load-bearing material *per se*, it follows that concrete takes first place as a self-sufficing fire-resisting constructional material. Terra-cotta can be used for floor construction in combination with steel girders, but the latter themselves require carefully designed protection from fire. It is unfortunate that hard-burnt terra-cotta, which has a fair capacity for load-bearing, is deficient in fire-resistance, while the more fire-resisting porous terra-cotta has no great strength, hence the use of terra-cotta for walls and columns other than as a veneer is impossible. As a floor constructional material terra-cotta has the advantage over concrete of requiring less time before loads can be applied, but has the disadvantage of being ill-adapted to filling irregularly-shaped spaces. The author expresses the opinion that it is not improbable that the greatest possibilities for future improvement in floor construction may lie in the combination of hollow tile and reinforced concrete.

Turning to concrete, the author shows that it is adaptable for most constructional purposes, and when reinforced provides in one and the same material the necessary elements of strength and fire-resistance. The design of concrete buildings, floors, columns, walls, etc., is discussed in detail, and the lessons learned from numerous fires are applied. So far as the composition of concrete is concerned, cinder concrete is considered to be the most satisfactory for fire-resistance, but the difficulty of obtaining a satisfactory grade of cinders has led to the almost universal use of other aggregates ; this is a difficulty which is not confined to America. The necessity of a layer of concrete from 1 in. to 2 in. thick for protection of reinforcement from fire-action is emphasised, and it is pointed out that although what is known as "full protection" from fire may be given by the adoption of certain constructional materials and methods, it does not follow that the building itself may not need entire reconstruction as the result of damage by fire, although its contents emerge practically uninjured. Hence, it is well for the designer to consider whether by means of an extra layer of protective material he can secure not only full protection of contents but sufficient protection of the building shell, that repairs after a fire need only comprise replacement of the external protective layer in the form of a coat of cement plaster.

The value of asbestos-cement products in connection with fire-resistance receives scant mention in this book, and when a report dated 1911 is described as recent, one's impression is confirmed that the work might have been brought more up-to-date in this revised edition.

The chapter on fire insurance is useful to the constructional engineer in showing how an insurance premium is built up, starting with a basic rate for the class of building, with additions for unprotected steel and other extra risks such as lift shafts, stairways, etc., and deductions for fire appliances; the importance attached to design of details is evident throughout the volume.

Fire-resisting design of special buildings such as theatres, schools and factories is dealt with, and valuable information is given concerning sprinklers, automatic fire alarms and other safeguards.

The author wisely points out that after widespread fires such as that at San Francisco, any one with prejudice in favour of almost any material or construction can find evidence to support his views. With the conflicting opinions which thus arise, it has been difficult for the layman and perhaps even the insurance surveyor to discern the truth, so that great service has been done to the public in summarising the evidence in such a way that reliable conclusions may be drawn.

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

In response to a very general request we have re-started our Questions and Answers page. Readers are cordially invited to send in any questions. These questions will be replied to by an expert, and, as far as possible, they will be answered at once direct and subsequently published in this column for the information of our readers, where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—ED.

Question.—E. A. R. writes :—Colouring Materials in Concrete.—I am at the present moment preparing drawings for a residential building in the tropics. I am extremely desirous of making it as interesting as possible. This is almost impracticable if the material of which it is composed—concrete in blocks—is left in its normal state. I therefore intend introducing colouring matter.

As red laterite is the only stone obtainable locally—though good granite lies farther inland—the blocks are formed normally of coarse sand.

I wish to obtain a strong white and varying shades of limestone blue and a warm red. The shades must vary to obtain the necessary texture.

I propose to treat the interior in other suitable colours, much as you suggest in your January issue.

Can you either supply me with this information, or name a standard work in which I shall be able to obtain it ?

Answer.—Concrete of a strong white colour can only be made by using white Portland cement, for which there are agents in this country, but a very fair white can be obtained by mixing 33 parts powdered chalk or barium sulphate with 67 parts finely-ground Portland cement and using sand as light as possible in colour.

A warm red is produced by adding 14 parts red oxide of iron to 86 parts Portland cement before mixing with the sand.

For various shades of blue, from 7 to 14 parts of azure blue or ultramarine should be used with from 93 to 86 parts respectively of Portland cement.

The actual shades of each colour for any specific purpose are best obtained by experiment. Care must be taken that only mineral pigments are used.

For information on both the subjects of your inquiry you should write to the Concrete Utilities Bureau, 35 Great St. Helens, London, E.C.3, for their pamphlets Nos. 11 and 14, which will be sent you post free.

THE BUILDING TRADES' EXHIBITION.

If it had but little entirely new to show, the Building Trades' Exhibition held at Olympia last month fully maintained the interest its predecessors have possessed for those concerned with the building and allied industries. But although there was nothing of a revolutionary character (can anything revolutionary be expected in an industry as old as that of building ?), there was certainly much of an evolutionary nature to be seen in improvements in existing methods and materials ; and, perhaps naturally, these improvements were mostly to be seen on the stands of the firms connected with concrete and cement.

On this and the following pages we give brief notes of the exhibits of special interest to our readers.

MACHINERY AND PLANT.

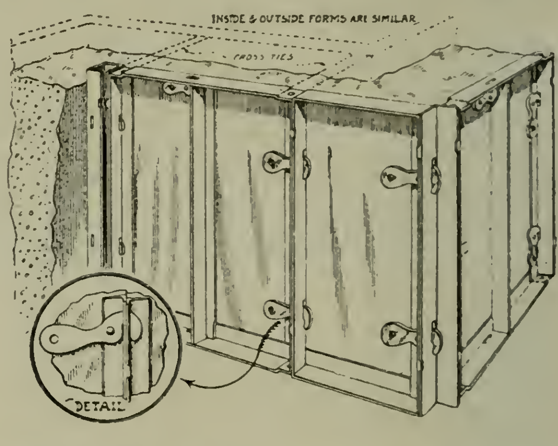
The well-tried concrete machinery manufactured by the Australia Concrete Machinery & Engineering Co., Ltd., of 606–7 Salisbury House, E.C.2, was shown in operation. The " Australia " block-making machine, which has an output of 400 plain slabs per 8-hour day with one operative, and the " Tonkin " mixer, which has a capacity of 60 cu. yds. per day (3 cu. yds. per batch), both embodying several improvements upon the already well-known types, and a new product of this firm, the " Speedy " crusher, a belt-driven machine for crushing clinker, bricks, or shingle, were on view. The last-named machine is erected as a complete unit with a petrol engine on a portable stand, and has every appearance as being a well-built and durable machine.

The simple method of erecting monolithic concrete walls known as the " Climbing Shuttering " system, was shown in operation by the Climbing Steel Shuttering Co., of 515 Queen's Road, Sheffield. By the use of light steel forms one-course high, which are folded up to form the successive courses, the cost of formwork is reduced to a minimum by this system, and no skilled labour is required for its operation.

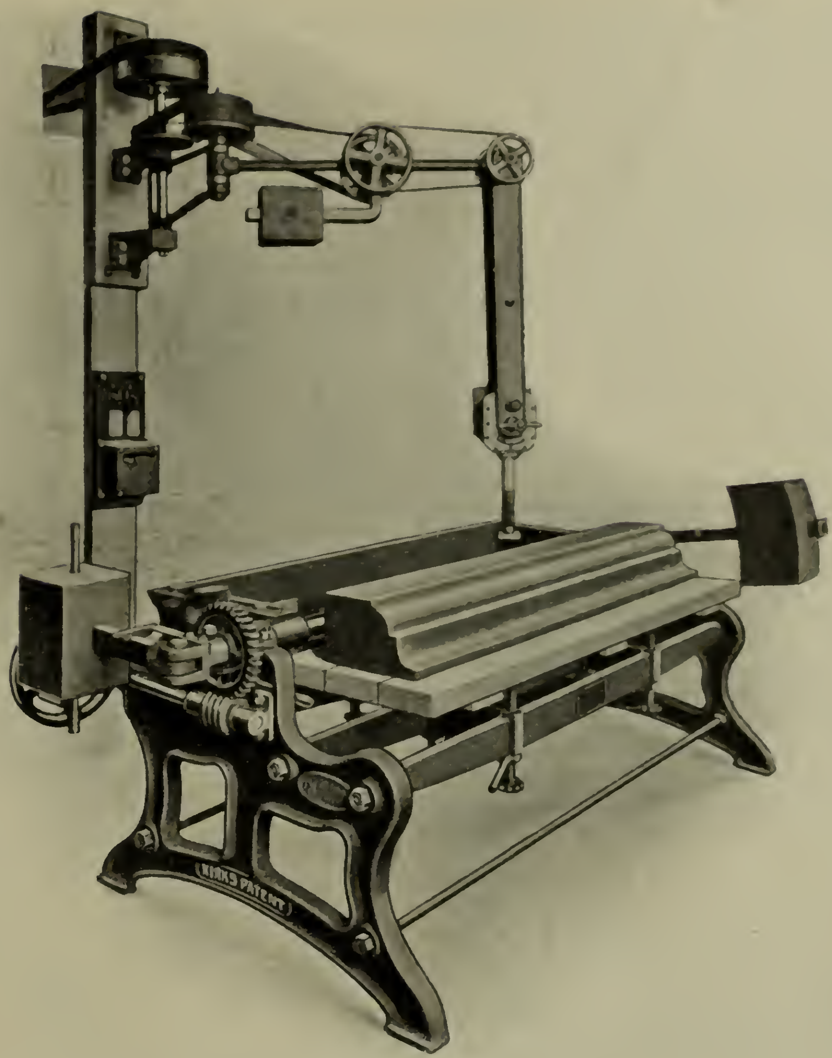
In addition to their well-known range of plant, Messrs. Gaston, Ltd. (Larden Road, W.3), had on view the " Reichert " system of metal forms for concrete wall construction. The standard size is 24 in. sq., and smaller sizes are made in order that any design may be followed. The plates are held apart to the desired thickness of the wall by spreaders, which are held in position by spikes placed through holes in the top of the form. When in position, the forms are locked together by steel clamps. It is claimed that, with reasonable care, these forms can be used upwards of 500 times.

A good selection of bar-bending machines specially suitable for bending concrete reinforcement was exhibited by Mr. W. Kennedy, of West Drayton. These tools, which are simply constructed and practically fool-proof, are made in various patterns for bending bars, angles, tees, channels, and flats on edge up to 2-in. sections, and are adapted for either hand or power operation.

The " Liner " concrete block and slab machine, which produces blocks up to 6 ft. long by 2 ft. wide, or a number of blocks to fill a mould of that size at one operation, was exhibited by the Liner Concrete Machinery Co., of Newcastle-on-Tyne. This machine is operated on the face-down principle, the blocks being released by inverting the mould. The machine is



" Reichert " Metal Forms.



MESSRS. KIRK & CO.'S NEW MECHANICAL TAMPER.

strongly constructed, easy to handle, and does not require skilled labour.

Three new productions of Messrs. R. H. KIRK & Co., of Newcastle, were shown here for the first time, namely, a mechanical tamper, a block-maker, and a kerb maker. The mechanical tamper, which requires a motive power of 1½ h.p., strikes 750 blows, each of 20 lbs., per minute, the total pressure per minute applied being thus 15,000 lb. It may be used with any type of block-making machine, and will tamp a 5 ft. sill in two minutes. The attachment containing the tamper may be reversed without stopping the machine, and gives a choice of a large or small faced tamper. The kerb and channel-making machine produces face-down blocks, 3 ft. long. After the concrete has been tamped, the mould is turned completely over, and the finished block deposited on a pallet ready for removal. The machine will make blocks of any section up to 12 in. by 8 in., and it is claimed that they can be turned out in less than three minutes each. The block-making machine is designed so that the block is made on the pallet on which it is to be removed; the block being released from the machine by raising the moulding box along guide rails at the sides.

The RANSOME MACHINERY Co. (1920), Ltd., of 14–16 Grosvenor Gardens, S.W.1, had two large stands, showing an extensive range of the latest constructional plant. The exhibits included a standard ½ cu. yd. batch type concrete mixer with belt drive fixed hopper, and road wheels; a new light-weight tilting-drum 5 cu. ft. concrete mixer, mounted on two wheels only for easy transport, and self-contained with 3 h.p. petrol engine; a "New Method" Aero concrete mixer (illustrated and described in our issue of December last); a section of a steel concrete hoisting tower with friction hoisting winch, hoist bucket, receiving hopper, and distributing chute attached; a 6 cu. ft. concrete tip-cart; type "D" steel sheet piling for coffer-dams, reservoir, canal, and marine work; and a 14-in. concrete pile-helmet for lifting, slinging, facilitating driving and protecting the heads of concrete piles. This exhibit was the most comprehensive of its kind in the Exhibition.

Messrs. Stothert & Pitt, Ltd., of Orchard Street, Westminster, showed their excellent range of concrete mixers, including the well-known "Victoria Standard No. 1" (unmixed capacity 14 cu. ft., mixed capacity 10 cu. ft.), fitted with automatic water tank and power-operated side loader, driven by an enclosed petrol engine, the whole mounted on road-wheel-truck with swivelling fore carriage; the "Improved No. 7 Victoria" (unmixed capacity 10½ cu. ft., mixed capacity 7 cu. ft.), fitted with automatic water tank and power-operated side loader, driven by an electric motor and mounted on road-wheel-truck with swivelling fore carriage, and the "Victoria H. M." mixer, fitted with power-operated side loader and driven by an electric motor. The last mentioned machine is rated at a capacity of 4½ cu. ft. of unmixed material and 3 cu. ft. of mixed, but we are informed that in actual practice they are giving outputs of 6 cu. ft. of dry material and from 4¾ to 5 cu. ft. of mixed ½-inch granolithic. This firm also exhibited the "Dri-crete" block-making machine, which produces blocks with a waterproof face, and a slab-making machine.

Among the exhibits of Messrs. Vickers, Ltd. (Broadway, S.W.1) were a portable concrete brick machine, designed to make concrete bricks of standard English dimensions; with this machine any thickness up to 4 in. may be obtained, and by a few simple adjustments various types of bricks may be made, such as arch bricks, flooring bricks, and tiles, without additional apparatus. It is claimed that with this machine a man and a boy can produce 2,000 bricks per day. A light, portable, and well-built machine for producing concrete roofing tiles of any desired colour was shown. This tile is interlocking, and consequently only a very small proportion of the surface is wasted in the overlap, and no trouble is experienced in fixing. Another advantage is that there is a considerable saving in battens, as the spacing of the battens is 13 in. Another exhibit was a portable machine for the manufacture of hollow or solid slabs for partitions, walls, or pavings, with square edges or with tongued-and-grooved joints. The slabs are made flat and not on edge, thereby allowing the surface of the slab to be finished off as desired. It is possible to turn out 200 18 in. by 12 in. by 2½ in. slabs per day per machine with one man. The "Vickers Hobbs" block machine, which makes hollow, plain, and rock-faced blocks of various sizes, was also shown; the blocks are made face downwards. A colour mill was also exhibited, which when filled with the correct proportions of cement and colour and turned by hand for twenty minutes produces a uniform colour for applying to tiles, brick, or slabs.

A new block-making machine shown by Messrs. R. G. Whittaker, Ltd., of Kingston-on-Thames, embodies a tamping apparatus which is automatically raised by means of springs after use.

An exhibit of much interest at the present time on the stand of Messrs. Henry Wilde, Ltd., of 66 Victoria Street, S.W.1, was samples of enamelled concrete. The enamelled surface, which appeared to be hard and very durable, may be applied during the manufacture of the blocks or afterwards, with either a rough or smooth finish. In addition to this firm's well-known range of hand and power concrete machinery (brick, tile, block and slab machines, mixers, and pipe, post, sill, lintel, coping, etc., moulds), a new slab-making machine (the "Rex") was on view. A feature of this machine is the automatic action by which the side and end pieces of the mould automatically collapse as the pallet containing the block is lifted, so that no time is lost in removing the sides and ends before the block can be removed.

Messrs. Winget, Ltd., of Grosvenor Gardens, S.W.1, one of the pioneer firms in the concrete machinery industry, showed a representative collection of their plant, which has been used on so many housing schemes and other work at home and abroad, including hand and power block-makers, mixers, crushers, and conveyors. Specimens of "Nonalike" concrete blocks similar to those used on the Liverpool housing scheme and elsewhere were on view and attracted considerable interest. A new type of "Winget" mixer, with an inclined spiral action, was shown. In this type of machine the cement, sand and stone are fed into a hopper at one end and pass through a revolving spiral inside the drum to the discharge at the opposite end; this action ensures a thorough mix by the pouring together of every particle of the batch, and a practically continuous discharge is obtained.

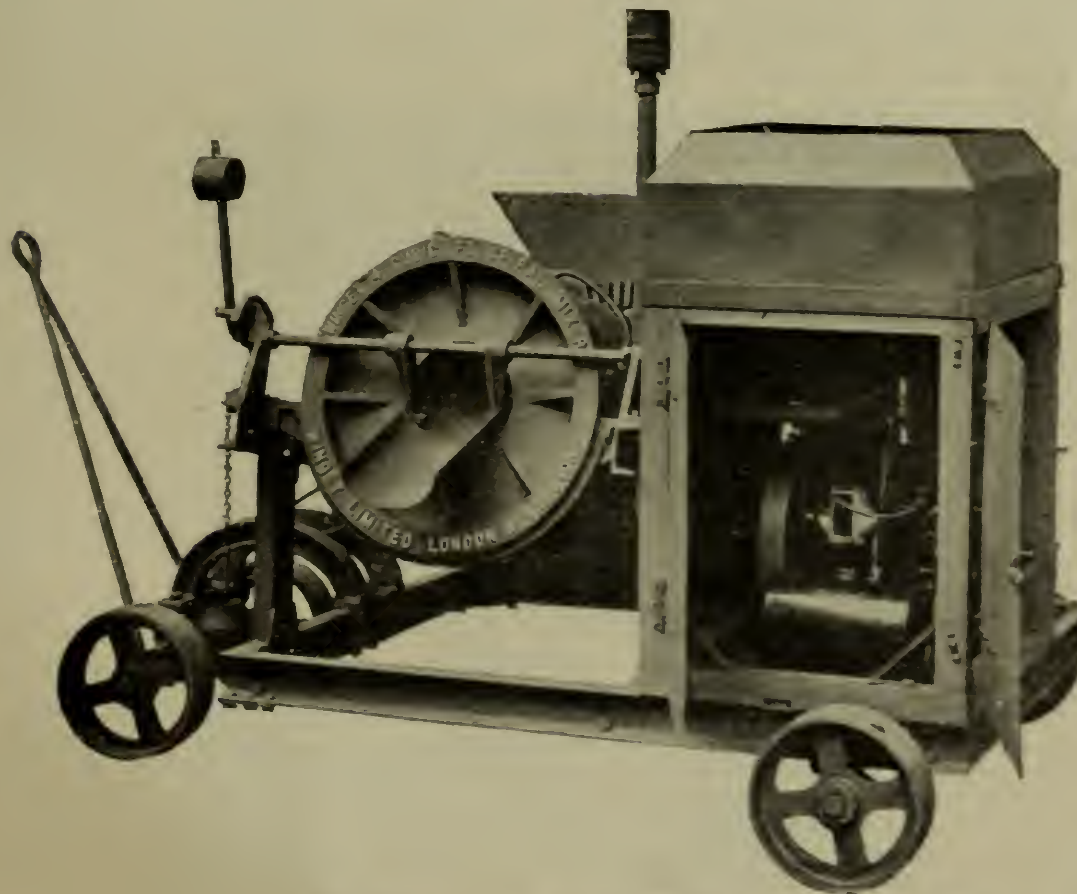
CEMENT AND WATERPROOF MATERIALS.

The chief exhibit of Messrs Building Products, Ltd., of 44–46 King's Road, S.W.3, was a practical demonstration, in the form of a sound-deadened room, of the heat and sound insulating properties of Cabot's quilt. This firm also specialises in concrete waterproofing and hardening materials, and samples were shown of "Bareau" (a powder waterproofer), "Pru-fit" (a waterproofing paste), "Prufitol" (a liquid for waterproofing existing buildings);

"Fillertex" (a plastic compound for filling cracks in roofs, gutters, etc.); "Ferrolithic" for hardening the surface of concrete floors; "Aqualithic" (a liquid for rendering floors dustless, waterproof and oilproof); and "Corundum" and "Corundite" for producing non-slip pavements and stair-treads. This firm also manufactures the well-known "Rigifix" bolt hanger sockets and inserts for fixing into concrete beams in order to avoid the necessity of cutting away to fix pulleys, etc.

A working model of a complete Portland cement plant attracted considerable attention on the stand of the CEMENT MARKETING Co., LTD., of Portland House, Lloyds' Avenue, E.C., which is the selling organisation for the Associated Portland Cement Manufacturers, Ltd., the British Portland Cement Manufacturers, Ltd., Messrs. Martin Earle & Co., Ltd., and the Wouldham Cement Co., Ltd. There were also shown on this stand samples of the companies' well-known brands of Portland cement ground to various degrees of fineness; cement at various stages of its manufacture; peat and sand briquettes of various ages, and cubes of various mixtures for testing; aggregates of various descriptions, both suitable and unsuitable, for mixing with Portland cement; a complete set of testing apparatus used in connection with the revised British Standard Specification, and a simple apparatus for ascertaining the proportions of cement, sand, and coarse materials necessary to obtain dense concrete.

The value of "Pudlo" brand cement waterproofer was demonstrated on the stand of Messrs. KERNER-GREENWOOD & Co., LTD., of King's Lynn, by means of specimens of treated cement and concrete surfaces exposed to running water and to oil; in the former case tanks composed of thin porous concrete blocks were shown to be quite impermeable when treated with a ¼ in. face of waterproofed sand and cement. Demonstrations were given with a new apparatus for testing the resistance of waterproofed cement mixtures to permeation by water under pressure up to 300 lb. per sq. in. The pressure was directly applied by means of a hydraulic screw pump. An attachment to the machine enabled waterproofed or non-waterproofed cement discs to be tested to destruction, and it was shown that discs of waterproofed cement (2 and 1 and 5 per cent. of "Pudlo" brand powder) ⅜ in. thick failed by fracture at an average pressure of 110 lb. to the sq. in. applied over a circular area 3 in. in diameter; when this occured there was



THE "WINGET" SPIRAL WET-MIXER (*see p.* 350).

Panel in Coloured Asbestos Cement.

no evidence of the penetration of moisture into the substance of the waterproofed cement.

ASBESTOS CEMENT PRODUCTS.

The decorative possibilities and uses of their asbestos-cement products were shown to advantage by Messrs. Bell's United Asbestos Co., Ltd., of Southwark Street, S.E. "Poilite" sheets, both plain and corrugated, diagonal tiles, Roman tiles, and pantiles in a tasteful russet brown were on view, and a series of photographs of the materials in actual buildings showed that they are as weather-resisting as they are attractive in appearance. The plain sheets used in the interior of the stand demonstrated the excellent effects which may be obtained with the material in various shades. Among the new products of the firm which were on view were asbestos-cement louvres and wall-copings. The louvres, which should be specially useful for use in buildings where they are exposed to chemical action, are made in standard sections in 4-ft. lengths. The ridging for wall copings is supplied in various widths and lengths, and forms a good protection for brick walls or stone balustrades.

In addition to asbestos cement building sheets and tiles, the British Everite & Asbestilite Works, Ltd. (Manchester), showed a wide range of rain-water goods, cisterns, etc., made in that adaptable material.

The application of "Fibrent" asbestos cement sheeting and tiles was demonstrated by the British Fibrocement Works, Ltd., of Erith, who showed the material in some attractive shades.

A new departure in asbestos-cement products was exhibited by the Société du Fibrociment et des Revêtements Elo, of Paris, in the form of panelling and relief decoration in excellent imitations of terra-cotta, various woods, bronze, etc. Particularly noticeable were some imitations of Gothic wood carving coloured to represent the originals, and decorative panels in imitation of bronze. The asbestos-cement products are undiscernible as such to the non-expert and as, so we are informed, the cost is less than wood, and the material in addition to being highly fire-resisting and vermin-proof has a much longer life than wood when in exposed positions, there should be a ready demand for them as a means of cheap and lasting decoration. Mr. A. C. Rennie, of 62 Oxford Street, W., is the London agent.

REINFORCEMENT.

Many of the well-known systems of reinforcement were demonstrated, a feature being the large number for concrete roads.

The British Reinforced Concrete Engineering Co., Ltd. (1 Dickinson Street, Manchester), had a separate stand devoted to "B. R. C. Fabric" for roads and slabs, and their reinforcements for columns and beams were shown by means of models.

The "Walker-Weston" patent system of interlocked double-layer reinforcement for roads and foundations, which is being extensively used by the Port of London Authority and many large municipalities, was exhibited on the stand of the Walker-Weston Co., Ltd. (7 Wormwood Street, E.C.2).

A selection of reinforcements was shown on the stand of Messrs. Brown & Tawse, Ltd., of 3, London Wall Buildings, E.C.2, special prominence being given to the firm's "B and T" square mesh for roads.

A variety of reinforcements was shown by the Barb Engineering Co. (5 Victoria Street, S.W.1), who, in addition to supplying reinforcements for all purposes, make a speciality of "Wonpees" fabric for roads. As its name implies, this is a jointless material supplied in rolls, the junctions of the wires being formed into a homogeneous mass by a special process.

The Expanded Metal Co., Ltd., of Petty France, S.W.1, in addition to the firm's mesh reinforcement which has been extensively used for roads, floors, walls and roofs, expanded metal lathing for plaster work, "Exmet" reinforcement for brickwork, and other specialities, showed a new product in "Rotary Diamond Mesh" expanded steel, which is specially suitable for concrete roads, foundations, etc. Another new product, an expanded metal ribbed lathing, was shown for the first time.

Among the firms specialising in reinforcement for concrete, Messrs. Johnson's Reinforced Concrete Engineering Co., Ltd. (Lever Street, Manchester), exhibited their well-known "Lattice" and "Keedon" systems for floors, roofs and walls, and beams and columns respectively, and "Bricktor" for brickwork and concrete block work. The "Lattice" system is being extensively used in the construction of reinforced concrete roads, and has the advantage that the edges are knuckled over and left smooth so that injury to workmen or passers-by is practically impossible. A new type of concrete flooring (the "Placet") was shown on this stand, in which the use of hollow concrete tiles strung together on steel rods and tightened by means of nuts forms strong and light floors or roofs without the use of shuttering; the blocks, bolts, nuts, etc., are supplied as required, and fitted up on the job by the contractor.

The well-known specialities of the SELF-SENTERING EXPANDED METAL WORKS, LTD. (110 Cannon Street, E.C.4), which aim at economising in reinforced concrete floor, roof, and wall construction by the elimination of shuttering, were shown to advantage. For floor and roof construction, "Self-Sentering" ribbed expanded-metal reinforcement does away with the need for the use of close-boarded timber shuttering. "Trussit" corrugated expanded-metal, when plastered to a thickness of 2 in., gives an excellent outside wall or partition, and is useful for walls of dwelling-houses, factories, garages, etc., and where sound-proofness has to be considered. This product has been used throughout for the walls of the new works of the Kent Port Cement Co., the Humber Portland Cement Co., etc. "Herringbone" is a rigid expanded-metal lath for fireproof ceilings, encasing stanchions, exterior walls of bungalows, and because of its rigidity will span across a wider spacing of studding than the ordinary lath, and also requires a minimum amount of plaster. We illustrate on next page an unusual photograph of a staircase at the Theatre Royal, Drury Lane, taken during the reconstruction just completed and showing the "Self-Sentering" reinforcement from below. The regulations of the London County Council do not permit of any wood being left in a theatre staircase, and the difficulty was overcome by the use of this material, which acts as both formwork and reinforcement. The products of this firm were used extensively in the reconstruction of Drury Lane Theatre, where the work was carried out at high speed. The three circles, each containing three rows, were all reinforced with "Self-Sentering," and were completed within fourteen days. The same material was used as the reinforcement of the flat roof, which contains spans up to 13 ft.

MISCELLANEOUS.

An extensive selection of concrete products was on view on the stand of the CROFT GRANITE, BRICK & CONCRETE CO., LTD. (Croft, near Leicester). These included concrete window dressings, drainage tubes, flags, kerbs, bases for gas stoves, and reinforced beams. Some excellent garden ornaments in concrete were also exhibited, as well as materials for concrete aggregates in great variety.

REPRODUCTION OF OLD OAK CARVING IN COLOURED ASBESTOS CEMENT (*see p.* 352).

"Self-Sentering" Reinforcement in the Staircase at Drury Lane Theatre (*see p.* 353).

The stand of the Empire Stone Co., Ltd. (231 Strand, W.C.2), formed an admirable example of the possibilities of artificial stone; the exhibit was in the form of a summer house of "Empire" stone to match Portland stone, on which was executed some good modelling. Concrete fence-posts, sign posts, steps, and various moulded decorative features were also shown.

Some realistic imitations of marble were shown by Messrs. Fassio Products, Ltd., of Winchester House, E.C.2. This material is formed of Parian cement coloured to represent any desired kind of marble on a backing of cement of a thickness dictated by the purpose for which it is to be used. This material, which is stated to be one-sixth of the cost of marble, has been used on many large buildings, and we are informed that some slabs built into the exterior of a building in Whitechapel twenty-five years ago are still in excellent condition.

The striking quality of the display of Messrs Sharp, Jones & Co., of Parkstone, Dorset, is no doubt to be attributed to the fact that they have had nearly fifty years' experience in the making of rock-concrete pipes. There is probably no better or denser granite than that from the Channel Islands, and the cement, which forms one-fourth part of the concrete, is specially ground to a fineness that leaves only 3 per cent. residue on a 180 mesh sieve. Besides examples of fifteen sizes of circular pipes, ranging from 12 in. to 6 ft. in diameter, there were shown bends, tapers, and junction pipes, while a new feature was to be seen in the form of oval or egg-shaped pipes. This firm's widely-used sewer manhole is made entirely of concrete, including, if desired, a heavily reinforced manhole cover and frame. Other objects shown were a sluice-gate or penstock for the Board of Agriculture, a still larger one for Egyptian irrigation work, channel-pipes with longitudinal joint, a universal inspection chamber for house drains, with light concrete cover, and interlocking roofing-tiles, all of concrete.

Concrete fence-posts, sign-posts, troughs, mangers and other of the many uses for which concrete can be used with advantage and economy on the estate formed a comprehensive exhibit on the stand of Messrs. Tidnams, Ltd., of Wisbech.

"Steel Concrete."

A Correspondent in a recent issue of the *Manchester Guardian* states that a method whereby the surface of concrete is protected from wear and tear by a covering of metal has been devised by Dr. A. Kleinlogel, Professor at the Darmstadt Engineering College, and is now being used by about twenty-five German firms. The new process is stated to enable a homogeneous metal skin of any thickness desired, and of remarkable resistance to mechanical wear as well as to hydraulic pressure, to be applied to the concrete, which, moreover, effectively counteracts the production of any dust. Extensive tests at the workshops of the Stuttgart and Darmstadt engineering colleges have shown such "steel concrete," as it is termed, to possess greater hardness than any natural or artificial stone, while being absolutely free from dust. The new material has, for instance, been found to be eight times more efficient than the best mechanically-compressed artificial stone slabs for wear, while in a comparison with high-grade granite steel concrete, on an average of 30 tests, proved 2·2 times better. The tensile and bending strength was found to be about twice as high as that of the best concrete, while the compression strength was 3 to 4 times higher, reaching as much as 630 kilogs. to the square centimetre. Special tests at the Darmstadt testing offices have shown a steel skin 5 mms. thick, applied by hand only, to stand a water pressure up to 14 atmospheres without any lack of tightness being noted. In experiments now being conducted the water pressure is to be raised to 60 atmospheres. It has been found that the steel concrete layer not only clings to fresh but also to old concrete.

MEMORANDA.

Exhibition of Contemporary British Architecture.—An exhibition of contemporary British architecture will be held in the Galleries of the Royal Institute of British Architects, 9 Conduit Street, W1., from November 1 to December 16, 1922. All architects in the British Empire are invited to submit their work. Work that has already been exhibited elsewhere will not be excluded, and exhibits must be confined to works executed or illustrations of works projected since the beginning of the twentieth century. Exhibits may consist of photographs, elevations, perspective drawings, and small-scale plans. The exhibitor may choose whether he will send any or all of these. Photographs of drawings are admissible, but not models. The last day for the receipt of drawings and photographs will be October 7, 1922. Further particulars may be obtained from the Secretary of the Royal Institute.

Cost of Concrete Roads.—The economy which may be effected in the initial cost of road construction (apart from the decreased upkeep charges) by the use of concrete roads, and the extent to which this type of road is being used in the United States, are shown by some returns just published for the State of Illinois, which show that the total cost of constructing 102 miles of concrete roadway, including materials and supervision, was very little in excess of 26,000 dollars per mile, whereas previous road construction worked out at an average of 39,000 dollars per mile. Altogether 390 miles of highways were built in the State last year, and a further 630 miles are in hand.

Pit-Shaft Lining.—In the course of a paper read before the Yorkshire County Colliery Managers' Association last month, Mr. T. Crosby (Manager of the Swinton Common Colliery), referred to the re-lining of an upcast shaft, 257 yds. deep, and 16 ft. diameter. Including three months' stoppage, the time taken to do the work was thirteen months, and 190 two-cwt. bags of cement were used. The cost worked out at about half the cost of brickwork.

Cementation and reinforced concrete were, he said, gradually coming to the front and replacing brickwork. He had not the slightest doubt of the suitability and reliability of reinforced concrete for shaft lining. A shaft lined throughout with reinforced concrete would prove less costly and more efficient than one lined with other material. In a pit bottom lined with this it would be possible to do away with flat sheets. Headgears were now being built with reinforced concrete.

Concrete Houses at £450 each.—On the Farnley Moor housing site of the Farnley Ironworks some fifty houses, the cost of which works out at an average of £450 each, have now been completed or are nearing completion. The houses contain a living room, kitchen and three bedrooms. They are built of hollow concrete slabs 2¾ in. thick, with a cavity of 3 in. which is filled with concrete after the slabs are in position.

Cement Drying Grounds.—Cement floors have been laid at the Cocoa Plantations at Bola Cameroon, for drying the wet cocoa.

A Mould for Concrete Blocks.—Mr. Daniel J. Walker, writing in the *Carpenter and Builder*, gives particulars of a mould devised by him for making concrete blocks. He states that whilst of course this method "cannot compete in speed with the excellent trade machines on the market, it is useful to those needing a few blocks, and unable to afford a machine, and possibly out of touch with a manufacturer of blocks.

"The most costly item in block-making is the provision of the pallets, or boards, upon which the block is cast, and upon which it must remain until hard enough to handle.

"The number which can be turned out at each gauging is determined by the number of pallets available. The pallet used is about 24 in. by 18 in., and can be made of three 1 in. boards 6 in. wide by 2 ft. long, nailed to four ledges out of 4 in. by 1 in. boards.

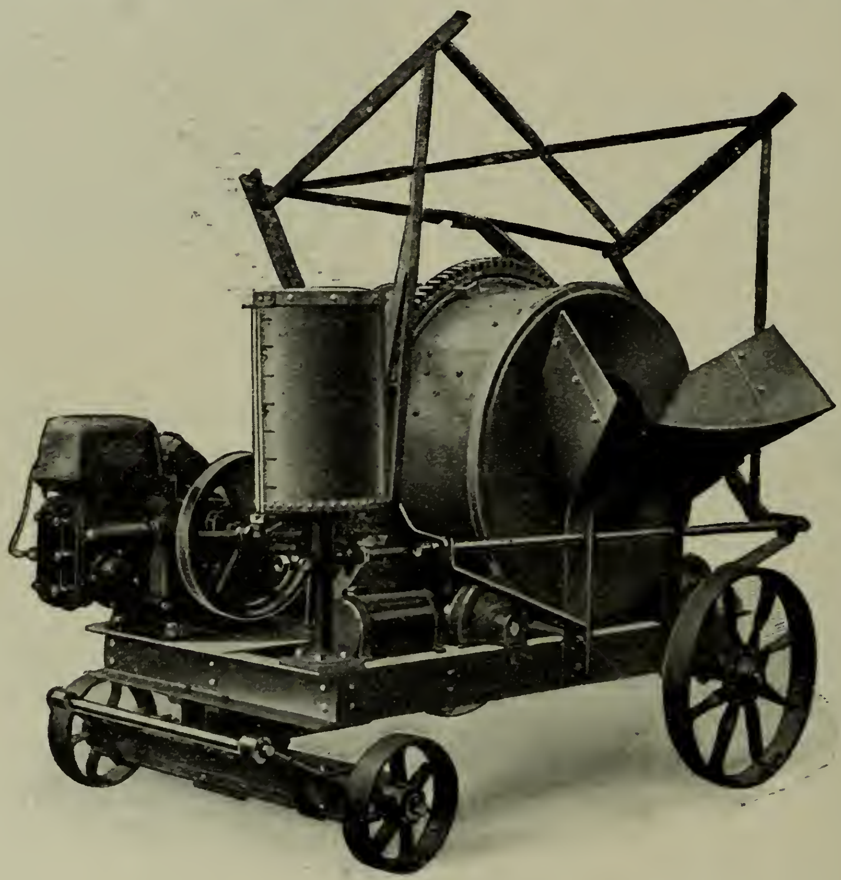
"The mould, as designed, makes a block 18 in. by 12 in. by 3 in., and is formed by four lengths of 2 in. by 3 in. wrot. deal, which is not fastened in any way to the pallet."

Concrete for School Buildings.—Manchester Education Committee is inquiring into the suitability of concrete for school buildings.

Change of Address.—Messrs. A. B. Searle & Staff, consulting engineers, have removed to 440 Glossop Road, Sheffield.

THE "ZENITH PUP" CONCRETE MIXER

SUBSTANTIAL CONSTRUCTION



COMBINED WITH LIGHT WEIGHT.

We illustrate here a machine of essential utility and economy, having an output capacity of from 2 to 3 cubic yards per hour, most suitable for moving about quickly from job to job. In these days of bad business, when it is essential to cut every possible expense, it will be well worth the trouble for those handling concreting jobs, however large or small, to make themselves thoroughly acquainted with the very many real advantages to be derived from using "Zenith" Mixers.

WRITE TO-DAY FOR FULL PARTICULARS.

Concrete Machinery Dept.

THE BRITISH STEEL PILING CO.

DOCK HOUSE, BILLITER STREET, LONDON, E.C.3

TRADE NOTES.

Reinforced Concrete Inspection Chambers.—Our attention has been called to Messrs. Plant & Pinders' invention for improved water-tight reinforced concrete inspection chambers, made in varying section, and rebated so that the height can be easily regulated to suit any required depth. These inspection chambers are specially adapted for water-logged districts and are manufactured in 36 in. by 18 in. and 24 in. by 18 in. by 24 in. deep, or larger sizes, according to order and to suit standard size manhole covers. It is claimed a saving of more than 50 per cent. is affected in time and materials, by using concrete in place of brickwork. Further information can be obtained from Mr. J. G. Randall, 30 Cremorne Road, S.W.10.

Messrs. Brown & Tawse, Ltd., of 3 London Wall Buildings, E.C.2, inform us that Mr. T. A. Farrar, who until recently represented them in London and the South-Eastern counties, is now no longer acting in that capacity.

PROSPECTIVE NEW CONCRETE WORK.

BLYTH.—*Water Supply.*—The U.D.C. is considering a proposal to construct a large new reservoir at an estimated cost of £14,000.

BRAINTREE.—*Sewage.*—The U.D.C. has agreed to carry out improvements at the Sewage Works.

CARDIFF.—*Road.*—The Corporation Public Works Committee has decided to purchase land for making a 50 ft. roadway in the Tyncoed Road from the City boundary for the distance of a mile and a half towards the Llanishen reservoir, and is proceeding to make a 36 ft. road at a cost of £26,000.

CLECKHEATON. — *Sewage Works.* — The borrowing of £9,975 by the Spenborough U.D.C. for the fitting of percolating filters has been sanctioned by the Ministry of Health.

COUNDON.—*Road.*—The Auckland R.D.C. has agreed to construct a new main road in this district.

DOUGLAS (I. of M.).—*Harbour Extension.*—The report of the Harbour Commissioners recommending the extensions of Douglas Harbour at an estimated cost of £282,000 was discussed by the Manx Legislature in the Tynwald. The scheme comprises the extension of the Red Pier by 400 ft., with the deepening of the Harbour bed for two additional steamers; also the construction of a viaduct in reinforced concrete to connect the Red Pier and the Victoria Pier. The Tynwald decided to forward the report of the Harbour Board to the Home Office for its consideration.

GLASGOW. — *Quay Wall.* — The Clyde Trustees' Engineer has received instructions to carry out the reconstruction of the Quay Wall at Plantation Quay, at an estimated cost of £45,000.

HALIFAX.—*Filters.*—The Town Council has obtained the sanction of the Ministry of Health for a loan of £32,831 to provide additional filters at the Salterhebble Sewage Works.

HEREFORD.—*Sewage Works.*—An inquiry has been held by the Ministry of Health into an application by the Hereford Town Council for permission to borrow £7,750 for sewage disposal works.

HERTFORD.—*Road.*—The Corporation has approved a scheme for the construction of a new road from Molewood to North Road.

HORNCHURCH.—*Road.*—The Surveyor to the Romford R.D.C. has been asked to submit an estimate of the cost for the construction of a new road.

KILDARE. — *Waterworks.* — The Waterworks Co. has decided to erect a new water tower, costing £4,200.

KIRKBY (NOTTS.).—*Reservoir.*—The Ministry of Health has held an inquiry into an application of the Kirkby Urban District Council for sanction to borrow £15,700 for providing an additional service reservoir.

LONDON.—*Grand Stand.*—The Crystal Palace Football Club has purchased 12½ acres of land in Homesdale and Cleston Roads for a football enclosure, which, when completed, will accommodate 45,000 to 50,000 people.

NAIRN.—*Harbour Works.*—The Nairn Town Council has approved of a scheme for new harbour works at a cost of about £35,420.

ORMSKIRK.—*Road.*—Sanction has been obtained from the Ministry of Transport for the construction of a new by-pass road by the Lancashire County Council.

PADIHAM.—*Water Supply.*—The House of Commons Committee on the Padiham (Lancs.) U.D.C. Bill has decided in favour of the need for an additional water supply. It is proposed to raise the Churn Clough reservoir 5 ft., increasing the storage capacity by 21,000,000 gallons.

PORTSMOUTH.—*Sea Wall.*—The Beach Committee recommends the Corporation to construct a sea wall and walk along the foreshore from the North End Recreation Ground to Horsea Lane.

SKEGNESS.—*Sewage Works.*—The U.D.C. is preparing plans in connection with the enlargement of the sewage disposal works, at an estimated cost of £15,500.

SMETHWICK.—*Gasworks.*—The Town Council of Smethwick proposes applying for sanction to borrow £180,000 for the erection of a gasworks.

STONE.—*Bridge.*—At a meeting of the

Stone Rural District Council the Surveyor, after presenting plans and specifications, was instructed to obtain tenders for a concrete bridge at Chebsey.

SUNDERLAND.—*Road.*—The Ministry of Health has sanctioned the borrowing of £20,000 by the Sunderland Town Council for the construction of a new road from Durham Road to Mount Road.

WALLASEY.—*Pier.*—The Ministry of Health has held an inquiry into the Corporation's application for power to enable it to reconstruct and enlarge Seacombe Pier and landing-stage, and for authority for the extension and enlargement of Egremont Pier and landing-stage.

WANDLE VALLEY.—The Ministry of Health has given its consent to the Wandle Valley Joint Sewerage Board to a scheme of sewerage and sewage disposal, at an estimated cost of £300,000.

WILLENHALL.—*Road.*—The Willenhall and Darlaston Councils have decided to seek the sanction of the Ministry of Transport for the construction of a new road between the two towns.

TENDERS ACCEPTED.

GLOSSOP.—*Sewage Outfall Work.*—The tender of Messrs. Collins & Co., at £25,182 10*s.*, has been accepted for the extension of detritus tanks, conversion of existing filter beds and the construction of new storm tanks and other work at Charlesworth.

HUNTINGTON.—The tender of Messrs. Morley, of Derby, at £10,795, for the construction of a sewage scheme at Huntington for the Cannock Rural District Council, has been provisionally accepted.

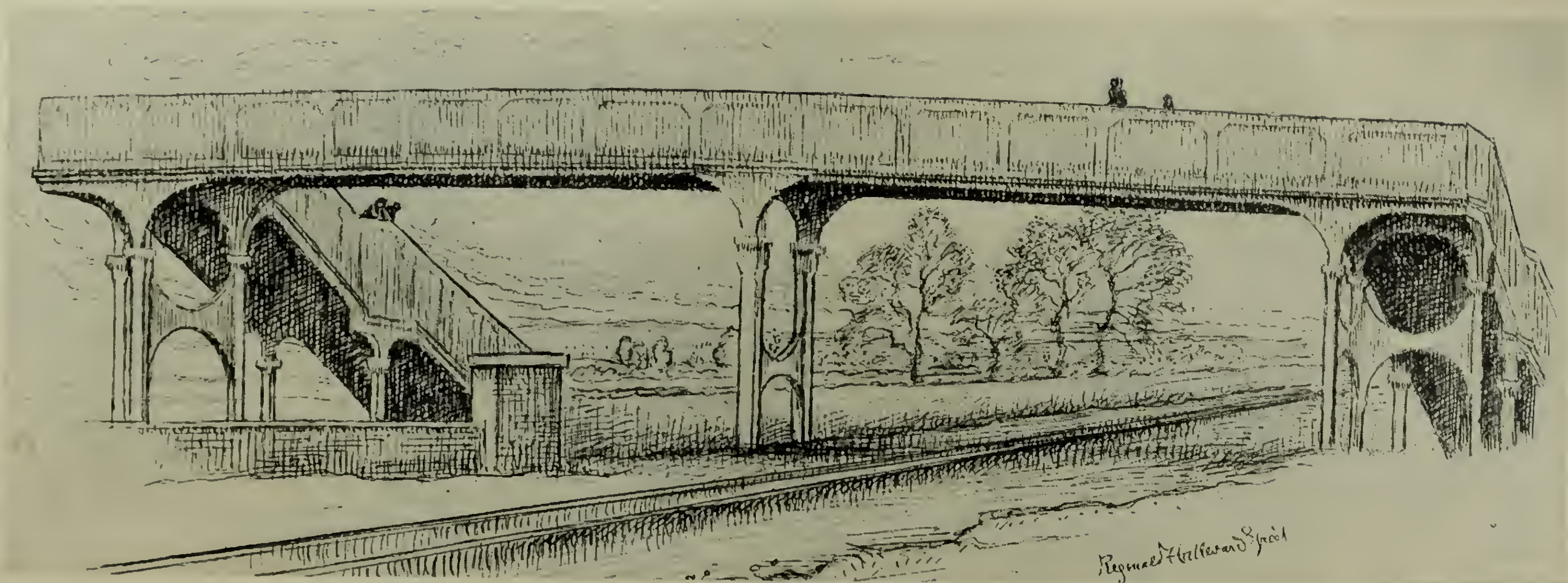
SLOUGH.—The offer of the Adams Housing Syndicate, Ltd., to supply and erect reinforced concrete posts for fencing the land recently acquired at Salt Hill has been recommended for acceptance by the Slough Urban District Council Committee at a total cost of £43 13*s.* 6*d.*

SWANSEA.—The tender of Sir John Jackson & Co., Ltd., London, has been accepted for the construction of the new dry dock at the King's Dock, which will be 500 ft. long and 75 ft. wide.

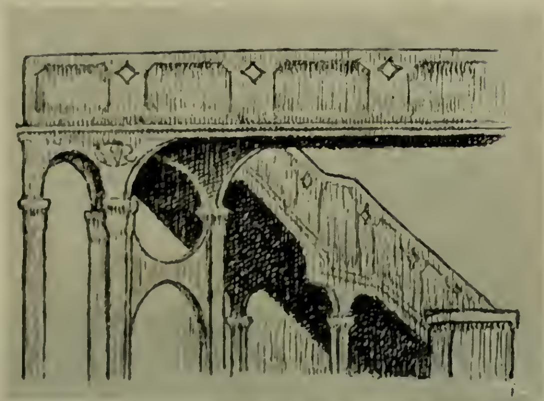
WHITBY.—The Whitby Waterworks Co. has accepted the tender of Messrs. H. Arnold & Son, Ltd., of Doncaster, for the construction of a reinforced concrete reservoir holding half a million gallons, at £3,357.

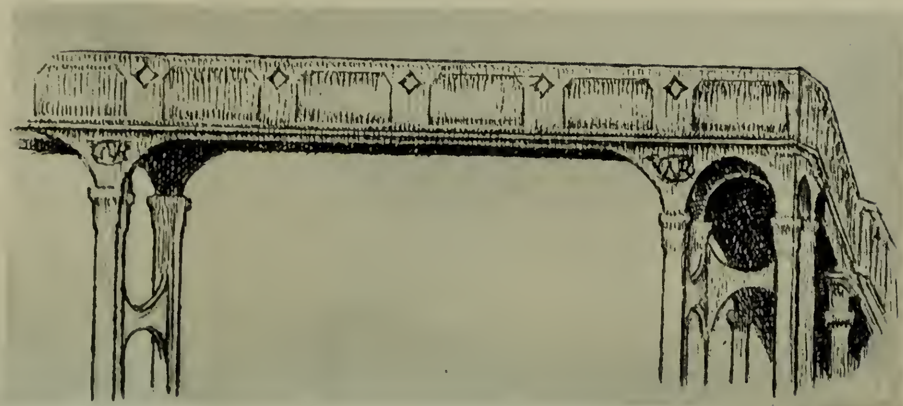
RECENT PATENT APPLICATIONS.

150,965.—C. J. M. Lancette: Reinforced concrete buildings.
153,599.—E. Lechat: Manufacture of faced building blocks.
154,903.—L. Faure-Dujarrie: Building blocks.
175,335.—W. Pearson: Concrete building blocks.
175,380.—O. F. Fischer: Concrete construction.
175,425.—W. Green and G. H. Dean: Concrete blocks.
175,487.—G. C. and R. E. Newton: Reinforced concrete vessels.
175,696.—C. Kelly and T. Beevers-Belvoir: Concrete blocks.
175,791.—E. Jones, E. Davies and S. Evans: Apparatus for delivering and spreading stone chippings and gravel.
176,465.—C. L. Brown: Mixing machines for concrete, mortar, paint and other materials.
176,589.—W. G. Heath: Device for supporting the shuttering employed in the construction of reinforced concrete floors and walls.
176,027.—T. Gibson: Concrete building.
176,030.—L. Green and W. C. Parsons: machines for use in manufacture of concrete railway sleepers and fence posts.
176,031.—H. E. Deyes: Interlocking building blocks and bricks.
176,054.—J. Macnaughton and W. T. Oldrieve: Roof construction.
176,133.—M. M. Smith: Wall construction.
176,249.—W. Green and J. H. Dean: Wall-tie.
176,275.—D. McLean: Wall construction.
176,815.—W. Adair: Concrete buildings.
176,868.—W. E. Clifton, J. S. Ewart and Clifton Ewart Construction Co., Ltd.: Concrete walls.
176,960.—F. Garthwaite: Walls.
177,051.—E. J. Frewen: Buildings and building-blocks.



Reinforced Concrete Bridge between East Acton and Wood Lane (G.W.R.).





The same bridge with suggestions for slight alteration including the addition of extra piers at the corners.

THE BRIDGE IN REINFORCED CONCRETE.

(*See page* 372.)

CONTENTS

Vol. XVII. No. 6.
June, 1922.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 6. London, June, 1922.

EDITORIAL NOTES.

THE COST OF BUILDING.

It has become so much a habit of the daily Press to accuse the building industry of profiteering that there is a danger that the relationship of the increase in the cost of building in proportion to the increase in cost of other commodities will be lost sight of by the general public. There is no doubt that the high profits received by both employers and employed in the period of prosperity which followed immediately after the Armistice was responsible for an impression that those profits could be maintained, with the result that high prices and high rates of wages were continued after the time when the community could afford to pay them. In most trades it is now realised that if industry is to continue at all prices must come down to something approaching a pre-war level, and the Board of Trade figures showing the cost of living figures to-day to be only 90 per cent. above 1914 level are a hopeful sign that before very long prices generally will reach a level at which intending purchasers will not hold back in hope of further reductions. In the case of the building industry, the financial failure of the Government housing scheme is in a large measure responsible for the agitation against the cost of building, and in certain sections of the Press the building industry alone is blamed for the high prices which have prevailed until quite recently. It is with interest, therefore, that we have read a publication by the Building Research Board (*A Graphical Cost Analysis of Cottage Building*, by W. H. Wainwright. London: H.M. Stationery Office, price 2*s*. 6*d*. net), which, in addition to many graphs which should be of considerable service to those engaged in the erection of working-class dwellings, gives some curves relating to the building industry generally. One of these graphs is specially illuminating as showing together the increases since 1914 of various commodities. From this we find that whereas in 1920 cotton soared to 460 per cent., iron to 340 per cent., wool to 440 per cent., and steel rails to 330 per cent. above the prices ruling in July, 1914, the cost of building at no time showed an increase of more than 175 per cent. Another interesting curve shows the cost of living and the cost of building from 1914 to January, 1922: this shows that building costs lagged at an average of about 50 per cent. below the general cost of living figures from the beginning of the war up to the middle of 1920, when the curves touch at the peak level of 170 per cent., and from that date the cost of living declined to 90 per cent. and the cost of building to 110 per cent. above July, 1914. It is to be regretted this curve has not been brought right up to date, for very considerable further reductions in building costs have taken place this year. This graph also gives curves on the same lines relating to the United States of America, and it is interesting to note that, although the increase in that country was more pronounced during the early years of the war, the curves bear a very strong resemblance, the apices being both at practically the same level at the same time (June–July, 1920). The price of building materials has been the cause of so much discussion that a graph setting out the fluctuations in nine of the chief building materials is also of much interest. Rainwater goods, as is well known, showed the greatest increase, reaching a level of 450 per cent. above pre-war figures, whilst Portland cement showed the least increase of all, at no time reaching more than 130 per cent. above 1914 prices. From the highest level of 1920 prices all round are coming down at a very rapid rate, and that decline is still continuing. In the case of the building industry, this decline is, we think, due more to the reduction in prices of materials than to decreased wages, for while wages are still approximately 120 per cent. above 1914 rates, the cost of a completed building is now only about 90 per cent. above the 1914 cost. A further reduction of 2*d.* per hour in the wages of the operatives has just taken effect, and it is to be hoped that as further reductions are rendered possible by the decrease in the cost of living they will be amicably agreed to by those concerned. The publication of the Building Research Board deals with results only, and does not attempt to analyse causes, but it should serve a very useful purpose in showing that although building prices have been high, they have been low in comparison with other commodities.

CONCRETE FAILURES.

THE general adoption of the British Standard Specification for Portland cement as the minimum standard of quality in this country has led to the disappearance of certain examples of defective concrete which were occasionally seen at the end of the past century, and it would not be an exaggeration to say that the few defects and failures of concrete which have occurred of late years have been due to lack of knowledge of the materials comprising the concrete. We regard it as one of our functions to keep our readers advised of the progress of investigation in this connection, and an example is to be found in this issue in the article by Mr. R. E. Stradling on " Some Causes of Cracking and Disintegration of Portland Cement Concrete." As knowledge of this description becomes more disseminated among the users of concrete it may be hoped that the occasional difficulties now experienced in the application of concrete will vanish. Indeed, it may be said that the present-day concrete user who experiences failure has only himself to blame, for a great deal of information is available regarding the fundamental conditions governing the production of good concrete. There is, however, one characteristic of concrete, not important enough to be classed as a defect but sufficiently noticeable to be irritating, which is apparently not entirely avoidable. We refer to the cracking of concrete due to contraction. The tendency to crack is inherent in concrete owing to the fact that it loses water—or dries out—during setting, and, although the cracking may be only superficial and possible of mitigation by reinforcement or by keeping the concrete wet until it is strong enough to resist the tendency to crack, there is no doubt that a concrete that did not possess this property would be welcomed. It is a feature that has no relation to the quality of the cement, but it is not too much to hope that developments in the industry may lead to the discovery of means whereby the whole of the water used for mixing concrete may be absorbed and retained by the cement, thus avoiding the loss of water by evaporation which causes the contraction referred to.

CONCRETE ROADS FOR INDUSTRIAL WORKS.

In these days of high production costs anything which will reduce the expenditure of an industrial concern, and thereby ultimately reduce the price to the consumer, deserves serious consideration. It is often the case that in the search for means by which economies may be effected attention is so much concentrated on comparatively small matters, such as eliminating unnecessary movements on the part of the workers, known as motion study, that methods by which considerable saving can be made are apt to be overlooked. Motion study, costing systems, etc., are moreover a continual source of expense whilst they are in operation, and, except in the case of very large works where the bulk of the processes are repetition, the cost of setting up and maintaining such systems is often out of proportion to the sums saved. One of the apparently obvious, although often overlooked, means by which expenditure can be reduced without the necessity for keeping up an expensive department is the provision of good access to a works. This has been realised by the owners of many large factories, and in view of the importance of the subject the following abstract from a letter from the proprietors of a large colliery is of considerable interest, and needs no comment: "The road, which is about 450 yds. long by 30 ft. wide, was constructed of reinforced concrete for the house-coal haulage traffic, which is performed by means of steam and motor lorries. Previous to the construction of this road the condition as regards house-coal deliveries was really bad; it was impossible to keep a road of any description, as the heavy traffic over the old road ground up the stone into fine powder and then became a puddle during the wet weather, burying the engine wheels up to the axles and causing all sorts of breakdowns to the lorries. The expense of keeping men continually on the road filling in with 2½-in. metalling was a serious item, and we found great difficulty in sending out 50 tons per day. To-day, with the concrete road, we are sending out 100 tons per day with perfect ease, no breakdowns, and no repairs. The road has been in commission now for about two years and has already saved some thousands of pounds. It is as good after two years' service as when laid down, and the upkeep up to the present has been nil.'

CONCRETE SEWER TUBES.

Although they are now being extensively used in this country, and with results satisfactory from the points of view of both efficiency and economy, one often reads accounts in which the use of concrete and reinforced concrete sewer tubes is deprecated as being somewhat in the nature of an experiment. In being subjected to this criticism concrete tubes are passing through the stage which has to be survived by everything which is new or but little known to the critic, whether it be an invention which proves to be of lasting benefit to mankind or the ideal of a politician. But if any doubt exists in this country as to the permanence of concrete sewer tubes, there is no scepticism on that score in America, where they have been much more extensively used over a longer period. A

Canadian contemporary gives some interesting notes on this subject, which have been gathered from municipal engineers, and which we summarise as follows : (1) A concrete pipe placed in 1873, and which had been in continuous service as a combined storm and sanitary sewer for forty-eight years, until dug up in 1921, was " in excellent condition " when excavated ; (2) Eight-inch and twelve-inch concrete sewer pipes laid between 1874 and 1879 " show no signs of deterioration, and have proved satisfactory " ; (3) Concrete pipes preferred and used in all sanitary and storm sewers—some have been in use for thirty years, but no failures have been experienced ; (4) Eight-inch concrete pipes in constant use as a sanitary sewer for thirty-five years on a 3 per cent. grade with high velocity " as perfect to-day as when cast, and fit to be relaid " ; (5) Concrete tubes laid in 1893 " show no visible sign of defect from the action of the sewage or sewage gases." A further article, by Professor E. R. Matthews, showing the principal forms of construction of concrete tubes which have proved successful in America, is given in this issue, together with a description and illustrations of a reinforced concrete culvert now in course of construction at Chiswick under the direction of Mr. Edward Willis, the Borough Engineer.

THE KNICKERBOCKER THEATRE COLLAPSE.

SEVERAL detailed reports have now been published on the causes of the collapse of the Knickerbocker Theatre, Washington, in January last, and these we welcome as directly refuting the statements which were frequently published at the time to the effect that the collapse was due to concrete. The building was not, however, of reinforced concrete at all, and we gather from the reports before us, which were prepared by experts, that the failure was entirely due to the bad design of the steelwork. The failure, nevertheless, has a moral for architects and engineers, for it appears that considerable variations from the engineer's design for the steelwork were authorised by the architect on the suggestion of the contractor, and were allowed to be carried into execution without being examined by either the architect or the engineer in conjunction with whom he was working. Without casting any reflection on steel erectors, it cannot be too strongly emphasised that the architect or designing engineer is primarily responsible for the soundness and stability of a building carried out to his designs, and it is unfair to the client to allow the work to be done by a contractor without thorough examination.

COLOUR IN ARCHITECTURE.

AN inspection of the designs submitted in the recent Colour Competition organised by the Royal Institute of British Architects leaves one with a feeling of disappointment that the opportunity presented was not fully grasped. Of the 170 designs, only two suggest the use of a concrete surface without any additional covering material, the majority being terra-cotta and marble on concrete walls. But why cover a structurally sound building with expensive materials when equally fine effects can be obtained, at practically no extra cost, by colouring the material of which the wall is actually made ? Just as there are ugly and beautiful bricks, so concrete may be dull and dreary or of a beautiful texture, and it seems to us that it is in the direction of producing a beautiful structural material rather than in covering up one material with another that the truest architecture and the cheapest buildings will be obtained.

THE TALLEST REINFORCED CONCRETE BUILDING IN THE UNITED STATES.

By A. E. WYNN, B.Sc., A.M.Am.Soc.C.E.

THERE has just been completed in the heart of the business section of New York an eighteen-story all-reinforced-concrete office building, known as the " Hide and Leather Building," situated close to the Manhattan Terminal of Brooklyn Bridge. The building was designed and constructed by Messrs. Thompson & Binger, Inc., engineers and contractors, of New York City. In its design and construction the most modern methods of reinforced concrete engineering were employed, and the building is a notable example of the scientific use of reinforced concrete both as a structural and as an architectural building material. Some of the constructional features are of particular interest, as it was the first time that they had been used on a large scale.

The building is eighteen stories high above the basement, the total height being 223 ft. from basement floor to roof. The floor area is approximately 75 ft. square, divided each way into bays 18 ft. by 18 ft. The floors are designed as " two-way " reinforced flat slabs, and are supported on exterior and interior concrete columns. Interior columns are

" HIDE AND LEATHER BUILDING," NEW YORK CITY.

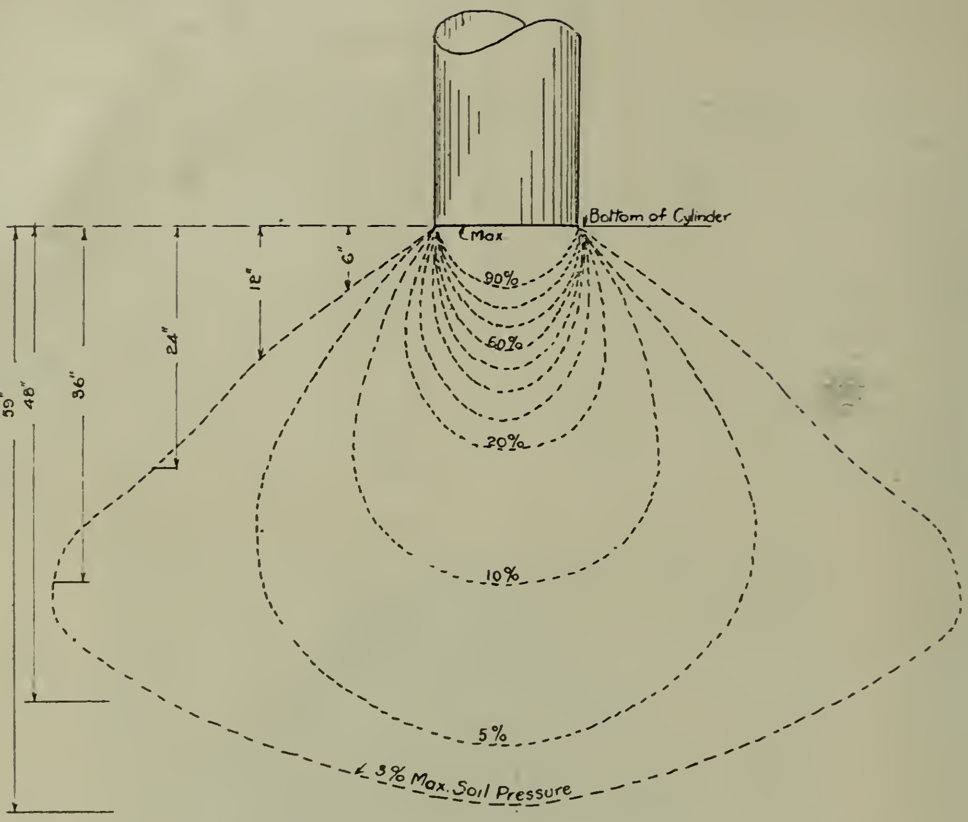


FIG. I BULB OF PRESSURE as determined by the Engineers of the Public Service Commission

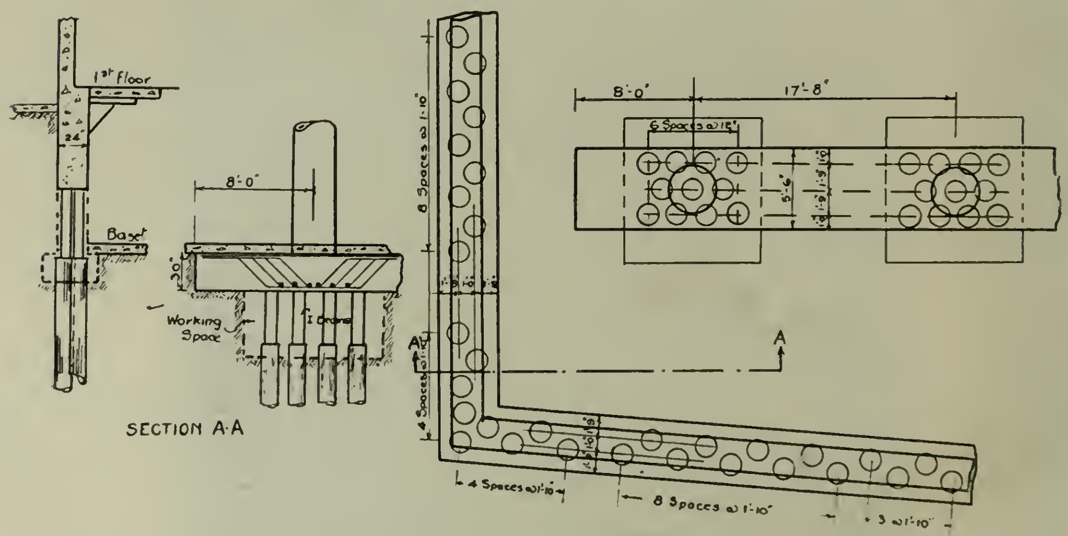


FIG. 2. PART PLAN of FOUNDATIONS (Shewing Pretest Piles)

FIGS. 1 AND 2. PRETEST PILES.

Fig. 3. Testing "Pretest" Piles under Exterior Walls.

[Note hydraulic rams and I-beams wedged between top of piles and bottom of wall footing; some of these I-beams are shown covered in.]

round, with moulded caps and octagonal depressed panels; the largest diameter used was 38 in. The whole structure, including the curtain walls and the 10,000-gallon water tank on the roof, is constructed of reinforced concrete, no structural steel or brick being employed.

FOUNDATIONS.

The most interesting constructional feature is the building of the foundations. Situated in what is known as "The Swamp," the bearing soil consisted of about 100 ft. of sand of various qualities underlying strata of muck, and peat. It was a serious problem to determine the best type of foundation to carry a building of this height and weight on an unstable bearing soil. Safety, economy and time of construction were all important points, and it was finally decided that the only method which could be used was that known as "Pretest" foundations. This part of the construction was sublet to Messrs. Spencer, White, & Prentiss, Inc., of New York City, who hold the patents for this type of construction.

Briefly, the method consists in driving sectional pre-cast concrete piles by hydraulic pressure as the building is constructed. The weight of the building during construction determines the depth to which the piles are driven, and they do not reach their final position until the frame of the building is completed. Their efficiency over ordinary pile foundations depends upon the "bulb of pressure" set up and maintained in the bearing strata beneath the bottom of the piles.

Before going into details it will first be necessary to explain the "bulb of pressure" (*Fig.* 1). The pressure in a soil carrying a load is distributed in all directions and varies in intensity from a maximum immediately under the load to a minimum a certain distance out from and beneath the load. The shape of the surface formed by joining up all points of equal pressure is approximately a bulb. It is the soil within the bulb which sustains the load by the cohesion of its particles. So long as the load is kept constant the bulb of pressure will be maintained, but if part of the load be removed the cohesion amongst the particles will be broken and the soil will be incapable of carrying its former load until a new bulb of pressure is set up by the addition of more load. This will explain why piles which have successfully withstood certain test loads will often settle when much smaller loads are later applied.

Owing to the danger of settlement ordinary pile foundations for this building were out of the question. The success of the "Pretest" system is due to the fact that after the bulb of pressure is created it is always maintained and no settlement occurs. It is important to note that the supporting power of the piles in this system depends almost entirely upon the bulb of pressure, and not upon skin friction.

The method of driving the piles was as follows: Shallow pits were excavated at the future locations of walls and columns, and in these were installed cylinders of steel casing, 3 ft. long and 20 in. diameter, the number depending upon the load to be carried. These were filled up with concrete, and on top were placed wooden blocks, carried up to the elevation of the underside of the future concrete cap or column footing. The caps were then constructed resting on the wood blocks and the ground on each side of the pits. The pits were maintained as working spaces throughout the construction of the building, and were about 4 ft. deep below the bottom of the caps.

The erection of the building was commenced immediately the caps were in place, which meant a great saving in time. Each cylinder was then jacked down, by two hydraulic rams, in successive stages as the building progressed, the weight of the building forming the reaction against which the cylinders were driven.

When the construction of the building had reached a certain stage, so that, without overloading the original 3-ft. lengths of cylinders sufficient reaction was provided, one cylinder of each group was driven into the ground until sufficient penetration had been obtained to enable the pile to sustain a test load in excess of that for which it was designed. After the first 3-ft. cylinder was driven, successive 3-ft. lengths of casing were added, continuity in the pile being obtained by sleeve connections and slots in the concrete. At a further stage in the construction another pile of each group was driven down to withstand a test load, and so on until by the time the frame was completed all the piles had been driven down and tested with an overload.

When each pile had been driven to refusal, the bulb of pressure was maintained in the following manner. For each pile an I-beam was cut to length equal to the exact distance between the top of the pile and the bottom of the cap, and was wedged in place between the two rams. The rams were not released until the beams were wedged in place, so that in this way the bulbs of pressure were maintained under each pile.

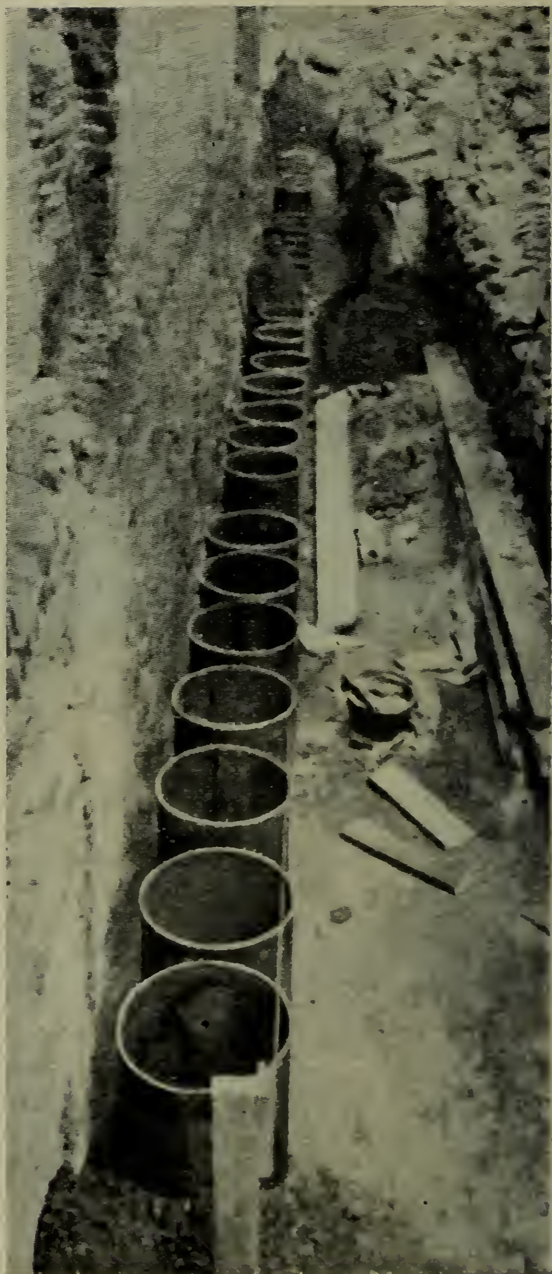


Fig. 4. Placing First Three-foot Lengths of Casing under Walls.

At any time the exact load a pile was carrying could be read from the gauges, and each pile was driven until it would carry the required load regardless of the depth to which it had to be driven. The interior pile caps or column footings were designed and reinforced as continuous beams (*Fig.* 2). Instead of using independent footings under the wall columns, the basement walls were designed as continuous distributing beams.

There are eleven piles under each interior column, carrying a total load of about 750 tons. The piles under the walls are in two rows, 1 ft. 10 in. on centre.

This method of dealing with the foundations proved very satisfactory, and it is felt that it was the only method which could have been adopted.

STEEL FORMS.

For the interior columns, column caps, depressed panels, and floor slabs, steel forms were used. This is the usual construction for the columns and caps, but is somewhat unusual for the slabs. For a building of so many stories, however, steel slab-forms proved more economical owing to the number of times they could be used, since wooden forms can only be used economically about four times. Another consideration, too, was the smaller cost of finishing the ceiling, as steel forms leave a smoother surface. The steel slab panels are 2 ft. by 8 ft., and were supported on wooden joists 4 in. by 6 in., 4 ft. apart, which were carried on posts 4 in. square and about 4 ft. 6 in. on centres. Two complete sets of metal forms were used, with sufficient extra panels to enable five floors to be shored at any time, so that while a certain floor was being poured the floor below would be completely shored with no panels removed and the next three lower floors would each be shored with eight posts to a bay, all panels being removed except one row down the centre of each bay (*Fig.* 5).

CONCRETE FINISH.

INTERIOR.—All interior surfaces were rubbed with an electric rotary carborundum surfacer, the finishers using specially-designed take-down rolling scaffolds, which reduced to a minimum the time required to move scaffolds. The surfaces were then sand-floated. The results are as good as plaster work, and besides being more economical are more permanent. All partitions are plastered with sand-floated finish to match the concrete.

EXTERIOR.—The method of finishing the exterior concrete surfaces is particularly interesting, as it is so often claimed that concrete cannot be used externally when the appearance of the building is important from an æsthetic point of view. Usually the lower two stories of a high building are faced in stone, but as it was desired to maintain the monolithic character of the building it was decided to cast the facing integrally with the concrete of the columns and curtain walls. About 1½ to 2 in. inside the forms, that is, for the depth of the fireproofing, ½-in. expanded metal was wired to the reinforcing bars. Inside this narrow space was poured the surfacing concrete, mixed very dry by hand and consisting of 1 part white Portland cement and 2 parts coloured aggregate composed of quartz, feldspar, and greenstone chips from $\frac{1}{16}$ to ¼ in. in size. The concrete was thoroughly tamped down with a specially-constructed tool, and was piled up higher than the

FIG. 5. METHOD OF SHORING SLAB AFTER ALL BUT ONE ROW OF METAL SLAB FORMS HAVE BEEN REMOVED.

ordinary concrete to prevent the latter reaching the surface. After the forms were removed any necessary patching was done with a similar mixture of facing concrete. The concrete was allowed to season all the winter, and in the spring was bush-hammered, which removed the cement and fine particles from the surface and exposed the coloured aggregate, producing a very fine surface finish indistinguishable from granite.

The surface of the upper sixteen stories was finished smooth with an electric rotary grinding machine and was then washed down with coats of waterproofing. The resulting appearance of the building is a fine example of what can be done with concrete as an architectural building material.

SPEED AND CONCRETING IN WINTER.

This building was constructed in the winter of 1920-21, having been started in October and the frame completed in March. The first floor was finished on October 21, 1920, and the sixteenth floor on February 24, 1921, that is, only four months to build fifteen stories, and out of this time fifteen days were lost due to weather conditions. This meant an average rate of one floor every six days.

In order to heat the material economically it had to be stored inside the building, so the first floor was shored to support any desired depth of sand and stone; actually, loads as high as 700 lb. per sq. ft. were placed on this floor. Over the rough concrete was placed a layer of planking, and upon this a system of perforated steam pipes about 12 in. on centre, the spaces between the pipes being filled with planks so that trucks could be driven over them. Valves were so situated that steam could be turned on in any desired bay. Sufficient aggregate for two floors was spread over the pipes and kept hot. Water was heated, almost to boiling point, by introducing steam into the water tank. Immediately the hot concrete was poured it was covered with tarpaulins carried on a frame of 4 × 4 resting on the surface of the concrete and the column dowels (*Fig.* 6). Heat was then supplied by "salamanders" or coal buckets on the floor below. The heat circulated between the tarpaulins and concrete through holes cut in the forms at the centre of each bay, and the steel forms themselves, being good conductors, helped in distributing the heat. The exterior wall openings were enclosed with tarpaulins, and salamanders were placed close to the walls (*Fig.* 7).

FIG. 6. PROTECTING CONCRETE WITH TARPAULINS IN WINTER.

In the whole of the building no frozen concrete was found. Owing to the rapid and winter work shoring was left in longer than usual, and five floors at a time were usually kept shored, although, of course, the slab forms themselves were stripped.

TESTS.

The strength of the concrete was not left to chance, as tests were made daily. In order to test the consistency of the concrete, or the amount of water that should be used, slump tests were made each day on a 6 in. by 12 in. cylinder, the required slump being between 6 and 7 in. To test the strength of the concrete, after each floor had been poured twelve galvanised cylinders 6 in. in diameter, enclosed in mailing tubes, were pressed into the concrete. The tubes quickly rotted and the cylinders were easily drawn, and tests were made on them at 7, 14, 21 and 28 days. A strength of 1,800 lb. per sq. in. was obtained on 1: 2: 4 concrete in 28 days. These tests provided a continuous check on the concrete proportions, and on the results of the tests depended the length of time the shoring was left in place.

This building, being the first all-concrete sky-scraper, will probably be the forerunner of many others of the same type, as it has proved conclusively that reinforced concrete can be used in competition with structural steel in the construction of tall buildings and in competition with natural and artificial stone as a facing material.

Fig. 7. Upper Stories Enclosed with Tarpaulins

BOOK REVIEW.

Reinforced Concrete Simply Explained. By Oscar Faber, D.Sc., A.M.I.C.E. London: Henry Frowde and Hodder & Stoughton. 77 pp. Price 5s. net.

One of the most important problems for an author is that of writing a treatise dealing with a complicated subject in a manner which will enable the uninitiated to follow and fully understand the principles which form the basis of all advanced theory and practical application, and in this volume the problem has been handled in an excellent manner. The matter first appeared in this Journal as a series of articles, and the publication in book form is the response to many requests for a simple book on reinforced concrete.

The work has been written to comply with the L.C.C. Regulations, and the standard notation has been used which will enable the reader to follow the subject in more advanced volumes.

The author has wisely introduced a chapter dealing with the design of compression members, wherein consideration is given to eccentric stresses in columns due to the bending of the beams supported; in fact, he has not presented the treatise in a simple manner by the omission of complex problems, but has rather made the complicated portions as simple as possible. This book gives an excellent grounding in the theory of design and the materials used in reinforced concrete.—A. L.

THE BRIDGE IN CONCRETE.

By REGINALD HALLWARD.

The bridge is such an important feature throughout the country, its appearance so much affects the surroundings in which it is placed, that the introduction of a new material for bridge construction is a matter of some importance. Many examples of reinforced concrete bridges call attention to themselves by the variation which they offer from what we are accustomed, and suggest possibilities not the less encouraging because they take a character of their own. The Romans are credited with the invention of the arch in bridge design, and the famous Pont du Gard built in three stages, serving the different purposes of a bridge over the river and an aqueduct supported by the uppermost tier of arches, which support a canal on a level with the mountains and 190 ft. above the river, is perhaps the most remarkable example. There is an old proverb which says " an arch never sleeps," and anyone acquainted with bridge construction will recognise the significance lying in this statement. Concrete, however, is more concerned with horizontal elevations, and the segmental or semi-elliptical form which now secures a low elevation for the roadway of bridges is one of the facilities which reinforced concrete offers for bridge building. The bridge of lattice construction, such as that over the river at Charing Cross, suffers from the entire absence of any attempt to conciliate the eye in its forbidding utilitarian character—it is as though we should wear our skeleton outside—but the concrete bridge without violation of the nature of its construction can be itself in a form which includes architectural character and is a pleasure to the eye.

Though left to make its own claims, and—for so one would imagine—with little of any conscious purpose beyond utilitarian fitness for service in its character, the reinforced concrete bridge has nevertheless succeeded in giving a very good account of itself. Free from any precedents of design in relation to appearance, it has already begun to create a design of its own, and the concrete bridge, in the frank acceptance of its own needs, has presented very creditable results already. Many of us will recall the case of the iron bridge over Ludgate Hill, which, though ugly in itself, has been made yet more unsightly as the result of the outcry which arose over it, and led to its being ornamented in order to make it, as it was supposed, more beautiful. But one cannot clap on beauty afterwards; it must grow through the construction and arise out of it, expressing the nature of the material. We do not want to see either Gothic or Classical detail on concrete bridges, but we should expect to see the resources lying in the nature of the construction and the kind of materials presenting us with forms of ornament which are native to itself, and which should be a slow growth out of its development. All this presents a subject of extraordinary interest in considering the future of concrete building. As it passes through industrial on to architectural use we may expect to see these possibilities developed, and shall need the formation of a school and workshops where training in the resources of decorative expression in various ways can be given. Such a class, under an able designer familiar with the application of ornament to architectural use, and with a mind fresh and inquiring enough to extend beyond the endless outworn derivative sources of ornament, the mere use and wont of design, would soon produce interesting results. The discoveries which such a new material offers when a wider range of treatment is found for it are endless. It is in this direction that a tradition would gradually be established really vital and native to the material, based not only on its strength and economy but on its adequacy for architectural construction.

In considering bridges we are not here concerned with the scientific principles of their construction. It is now well known that the concrete bridge is cheaper than the unprotected steel bridge, and, as it has manifestly more opportunity lying in it for architectural character, it is to be preferred, because without any considerable increase of cost a becoming appearance can be given to it. It will hardly be doubted that in adding beauty to use we do a better thing ; on public grounds there is evident advantage in adding agreeable appearance to fitness for use, and that appearance should naturally grow out of it. To reconcile industrial needs with this higher interpretation would be a great step towards that amelioration of industrial conditions which have in the past so often overruled the more human claims that lie in this direction, and with this end in view it is essential that concreters should be trained beyond the industrial uses of the material.

The carving of cement blocks as sculpture has already presented some excellent examples of the sculptor's work. Mrs. Stabler is one who has, I believe, executed some delightful work in this material. Its fitness for ornament appears limited only to the right application of the material. In concrete sculpture the necessity for avoiding pockets and for planning the work to throw off the water without settling is no more than part of the ordinary conditions governing work which is to be exposed to the weather, and the methods of hardening now applied secure strong resisting power to the material. All architecture is based on construction, expanding or flowering into artistic expression, and this æsthetic development should be as natural and suitable to concrete as to any other older material, with all the possibilities lying in a new field so little developed as yet.

The footbridge illustrated in the Frontispiece crosses the G.W.R. between East Acton and Wood Lane, and, though perhaps less successful than others, it justifies itself over open steel construction. It is at any rate clad in a suitable vesture, and is not a skeleton. The bridge is wholly unornamental except for the recessed panelling of the parapets which enclose it on each side of the footway. Here and there, where they might have been modified to the needs of the eye, there are features, such as the projecting and unsupported ends, which have an uncomfortable effect. While no doubt independent of more support than that which is provided by the construction, it needed that this appearance of support should also be given—the satisfaction of the eye as well as the mind. The bridge also conveys a slightly top-heavy impression, which is exaggerated by the contrast between the uniform solidity and height of the parapet walls and the slender supporting piers. It would be very much improved if these piers could be a little thicker, especially as their actual size is also further diminished by the chamfering of their edges. If the parapet were perforated in some way to avoid this impression of bulk it would give attractive lightness to the bridge. In the other illustrations is suggested, with due diffidence, what seems a possible amelioration. The spandrils which connect from the piers might, with advantage, be a little larger. It is a small matter, but the ornament of the spandrils with three perpendicular lines might have been left out, though we can imagine a well-designed monogram "G.W.R." incised in these spaces looking suitable. But these are small matters beside the virtue which lies in a construction growing naturally out of the materials and expressing itself through them; with this as the foundation, and freed from any of the old precedents and conformities, bridge building in concrete should create its own architecture, its own beauty.

I have taken the liberty of suggesting small alterations in the bridge, as shown in the sketches, which I think would do no violence to any structural necessity, while they would make all the difference to its appearance. The changes I suggest are limited to two or three only. There is a great deal that is good in the bridge, and the G.W.R. is to be congratulated on its enterprise in planning these bridges in a new material with so much success. The first need is a greater thickness in the supporting piers to give the sense of more adequate support, not because they are not strong enough as they are, but to meet the need that construction shall satisfy the eye as well as the mind. The second lies in the need to relieve the sense of top-heaviness, which arises from the solid character of the parapets which enclose the footway mounted on such slight piers; if these were perforated in some way to let a little light through, the relief would be immediate. I have suggested diagonal-shaped openings between the sunk panels on either side, as one way of meeting this need. But the failure to satisfy the constructional claims of the eye is most felt in the projecting unsupported ends of the bridge, which hang in the air. I have shown how much improved are the ends by adding a pier at each corner. If this bridge were a lattice or of other open steel construction only it would be different, but the use of reinforced concrete brings its own requirements. The designers had evidently in mind to make it becoming to the eye, and it is an interesting example of a stage in the transition from industrial to architectural use not yet reconciled. I have shown in the drawings unsupported ends. I, of course, do not speak as an engineer but as an artist, but if concrete—and this bridge is proof of this further aim: of the desire to work through construction to becomingness—is to reach its full development as a building material full allowance must be made for the satisfaction of the eye, quick to perceive the lack of the union between use and beauty.

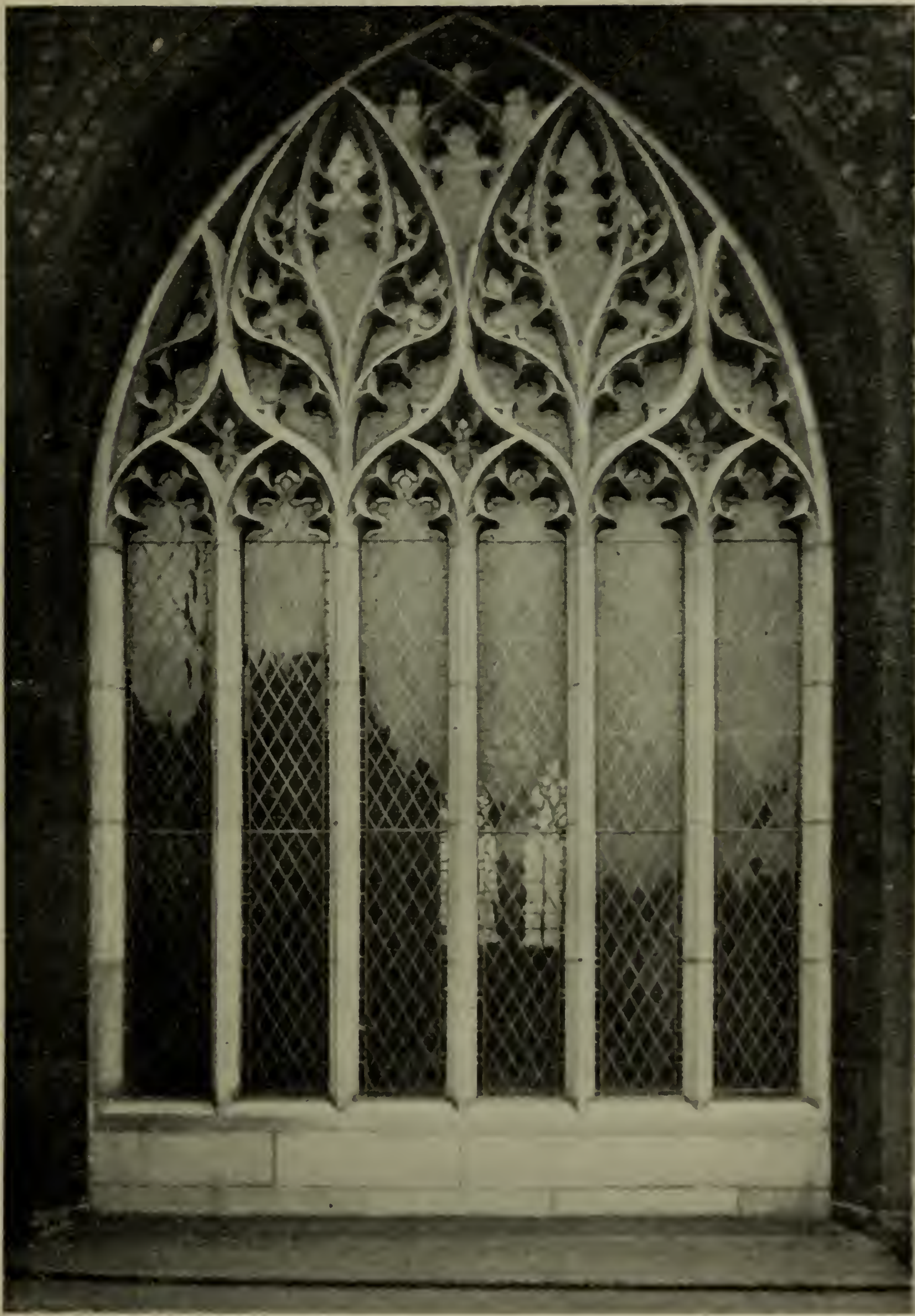
A CHURCH WINDOW IN CONCRETE.

Perhaps no better example of the use of concrete for other than utilitarian purposes could be found than the war memorial window at St. Augustine's Church, Hull, which we illustrate on page 375.

St. Augustine's Church was built about thirty years ago from designs of the late Temple Moore. The west end, where a tower was intended to be erected, has not been completed, and as there was no probability of a tower being erected it was decided to finish the exterior of this end of the church. The outer arch, of red Mansfield stone (seen in the illustration), was already in position and accuracy was necessary in the setting-out and in making the moulds. The window was fixed without any cutting being required. The window is in keeping with the older tracery of the nave windows.

The window is 20 ft. high by 13 ft. wide inside the original arch; the jambs are 14 in. by 4¾ in.; the main mullions 14 in. by 6 in.; and the tracery 11 in. by 3¾ in. and 9 in. by 3¾ in. The sills were reinforced with ½ in. steel rods. It was not considered necessary to reinforce the jambs, mullions, and tracery. The concrete was formed of 2½ parts fine crushed granite and sand, and 1 part Portland cement. The cement and aggregate were first thoroughly dry mixed by machinery, the wet mixings being hand made.

The window was manufactured by the Hull Concrete Stone Co., from the design of Mr. H. Andrew, A.R.I.B.A., of Custom House Buildings, Hull, the cement throughout being supplied by Messrs. G. & T. Earle, Ltd., Wilmington, Hull.



War Memorial Window in Reinforced Concrete at St. Augustine's Church, Hull.
Mr. H. Andrew, A.R.I.B.A., Architect (see p. 374).

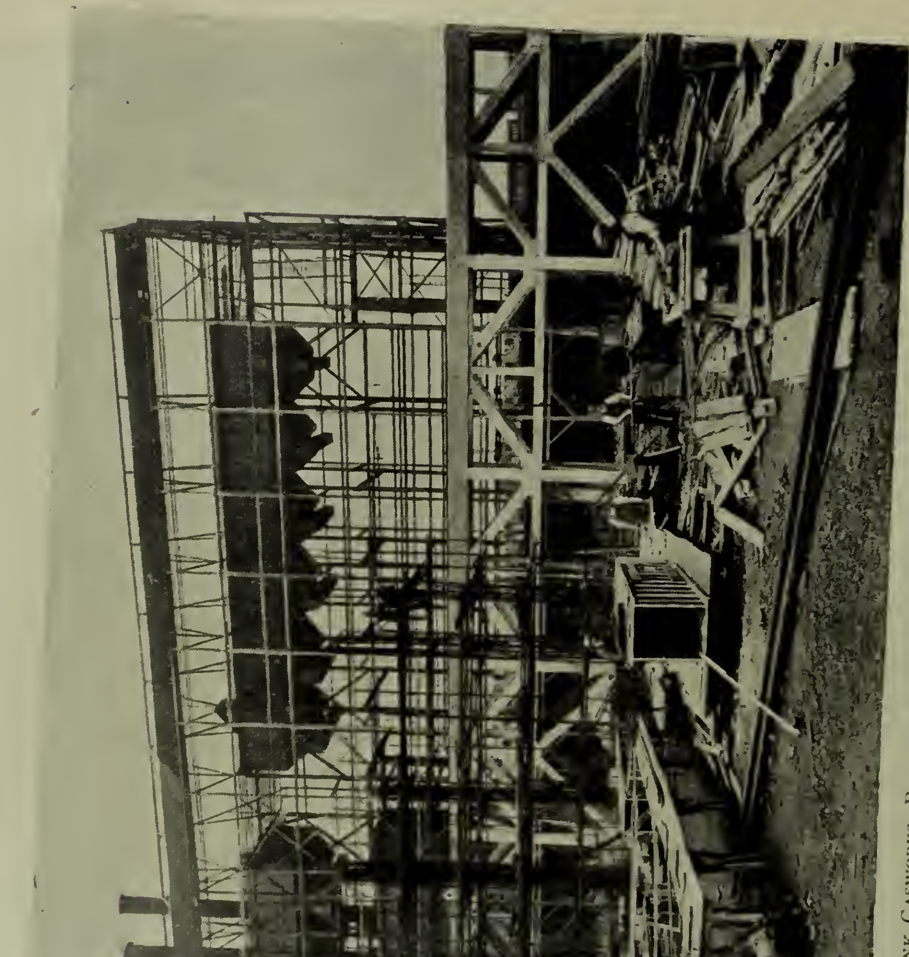


Fig. 1. Greenbank Gasworks, Blackburn (see p. 377).

CONCRETE AT GREENBANK GASWORKS, BLACKBURN.

THE accompanying illustrations show details of the reinforced concrete work erected at Greenbank Gasworks, Blackburn, in connection with the new installation of continuous vertical retorts which has been erected by Messrs. West's Gas Improvement Co., Ltd., of Manchester, to the general designs of Mr. G. P. Mitchell, the Gas Engineer and Manager to the Corporation.

The reinforced concrete work consists of pile foundations to the retort house, a coal breaker pit in connection with the coal-handling plant, a system of coke storage hoppers, and a crane gantry carrying a steam locomotive crane for transferring the coke from the retorts to the storage hoppers.

Before commencing the work an examination of the site was made, and the subsoil found to be of very poor quality, consisting of 2 ft. made ground, 2 ft. 6 in. loamy gravel, 2 ft. 6 in. shale, and 2 ft. 6 in. marl, which then gave way to soft wet yellow clay, this continuing to a great depth. Water was met with just below the surface, but its level varied considerably with the seasons. It was accordingly decided to carry the whole of the elevated structures on piles, and for a variety of reasons it was decided to employ "Simplex" piles cast *in situ*.

The whole installation for the manufacture of a nominal output of 3,000,000 cu. ft. of gas per day consists of 96 retorts in two benches of six settings each, the coal-breaker pit being situated outside the retort house on the producer side and in the centre. The main loads from the retort settings are carried on 16-in. diameter concrete piles, cast *in situ*, and varying in depth from about 30 ft. to 40 ft., reinforced in the upper 25 ft. of their length by six ¾-in. diameter mild steel round bars, with the necessary wire links and stiffening rings to permit handling and lowering into the hollow steel tube.

On the producer side the piles are placed so as to give the most equal distribution of load which the available space permitted, and are joined at the top by a continuous cap of concrete 3 ft. thick and suitably reinforced. The foundations for the producers project out from this continuous cap, and are monolithic with it but only 30 in. thick. The engineering brick piers for carrying the retort superstructure are built direct on to the pile caps, and were commenced as soon as the pile caps were set.

On the non-producer side groups of piles are provided under each column joined by pile caps 3 ft. thick and suitably reinforced; the main concrete columns, 11 ft. centre to centre, 23 in. by 23 in. in section, and 10 ft. 1 in. high, reinforced with eight 1¼-in. bars, and ¼-in. diameter links, are built monolithic with the caps. These piers are encased with brick, but were shuttered in the ordinary way, as it was found that there was a risk of the brickwork being cracked if the brick shell was used as shuttering to contain the liquid concrete.

The side framing of the retort house, which is 50 ft. wide by 174 ft. 6 in. long, centre to centre, is carried on sill beams, for the most part 22 ft. span and 36 in. by 24 in. section lightly reinforced. These sill beams are in turn supported upon 16-in. diameter "Simplex" piles spaced so as to load them equally to the predetermined figure, no support being assumed from the ground under the beams.

Fig. 1 shows generally the nature of the loads carried, and represents the retort house with the steelwork erected and the building of the retorts commencing. *Fig.* 3 shows the retort house further advanced, with the side brick panel walls filled in. The total number of piles employed in the retort house section of the work is 202.

The coal breaker pit (*Fig.* 6) presented some difficulty, as it was necessary to construct it without interference with the

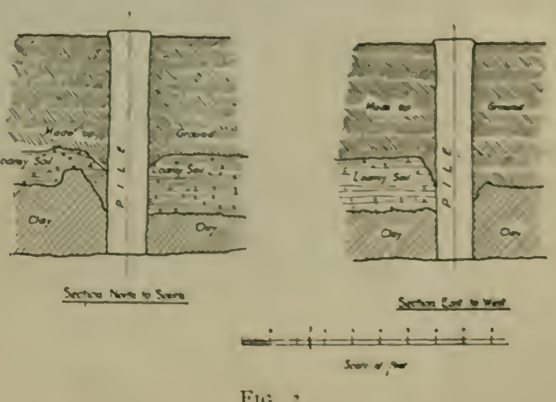


FIG. 2.

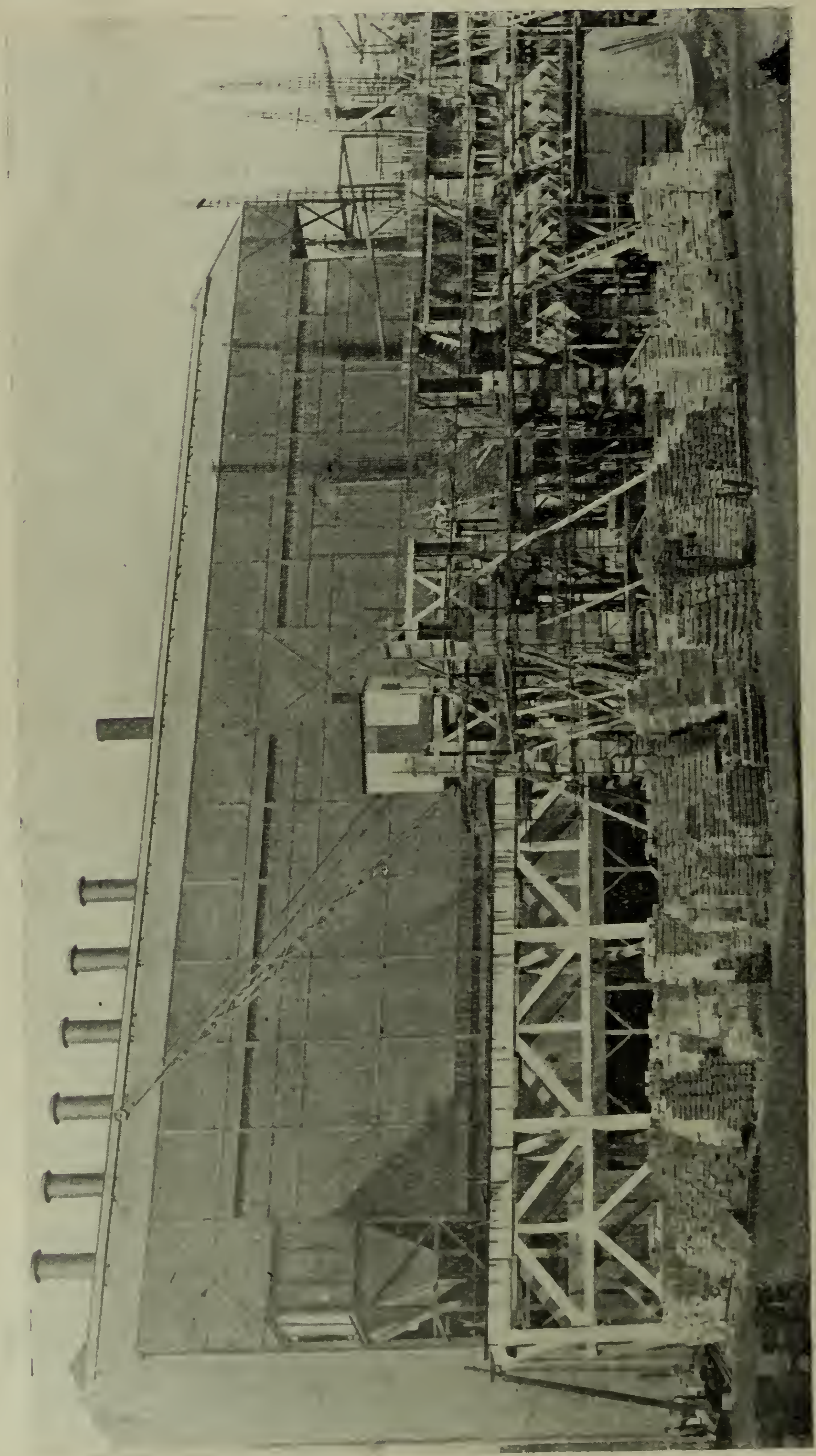
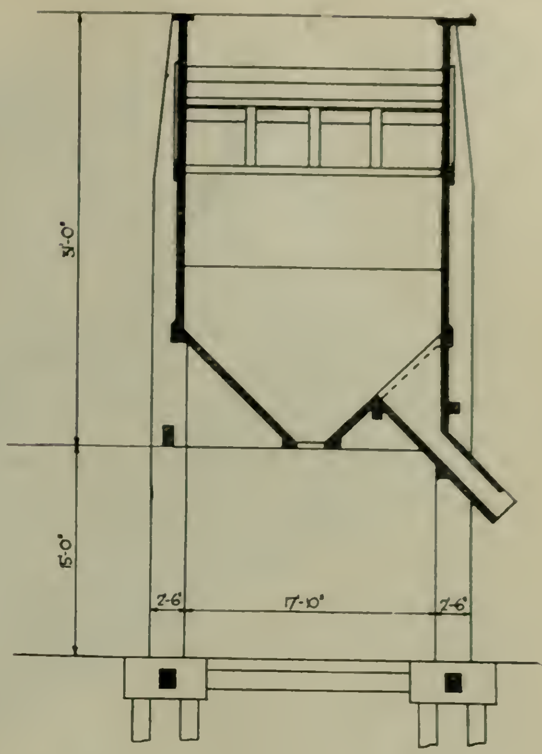


Fig. 3. Greenbank Gasworks, Blackburn.

working of the existing overhead steel gantry carrying coal trucks, and the site was waterlogged a short depth below ground level. Continuous pumping was necessary night and day, and various small streams of water were tapped, the clay at that point being very greasy and slippery and exerting considerable pressure, both lateral and vertical. The greatest depth is 17 ft. 6 in. below the retort house floor level, and as a result of the care taken it was possible to get a dry pit without recourse to any special surface treatment.

The position and details of the pit having been revised, after the piles and sill beams for the side framing of the retort house were constructed it was found necessary to destroy a part of two of the piles and bond the bars into the coal-breaker pit wall ; one pile was demolished after examination to a depth of 20 ft. and found to be perfect in every way. Before the pile was broken up (as it came in the deep portion of the pit) it was thought that useful information might be obtained as to the manner in which the strata passed through had been bent down by the action of drawing the steel tube. *Fig.* 2 shows the information obtained, and seems to bear out the suggestion that it is not safe to drive *in situ* piles nearer together than 3 ft. 6 in. centre to centre, and that 4 ft. centres is a safer dimension to adopt to be quite sure that a newly-cast pile is not damaged by driving the tube for the next pile.



CROSS SECTION.

Fig. 4.

The crane gantry, shown in *Figs.* 1, 3, 7, and 8, is 200 ft. long, in ten bays of 20 ft. centre to centre between columns, in a longitudinal direction, 9 ft. centre to centre at the base in cross section at ground level, and 7 ft. $2\frac{7}{16}$ in. centre to centre at the top at a height of 18 ft. 6 in. above ground level. The gantry carries a steam locomotive crane, designed to carry two tons at 35 ft. radius with the usual over-load, and to carry other loads

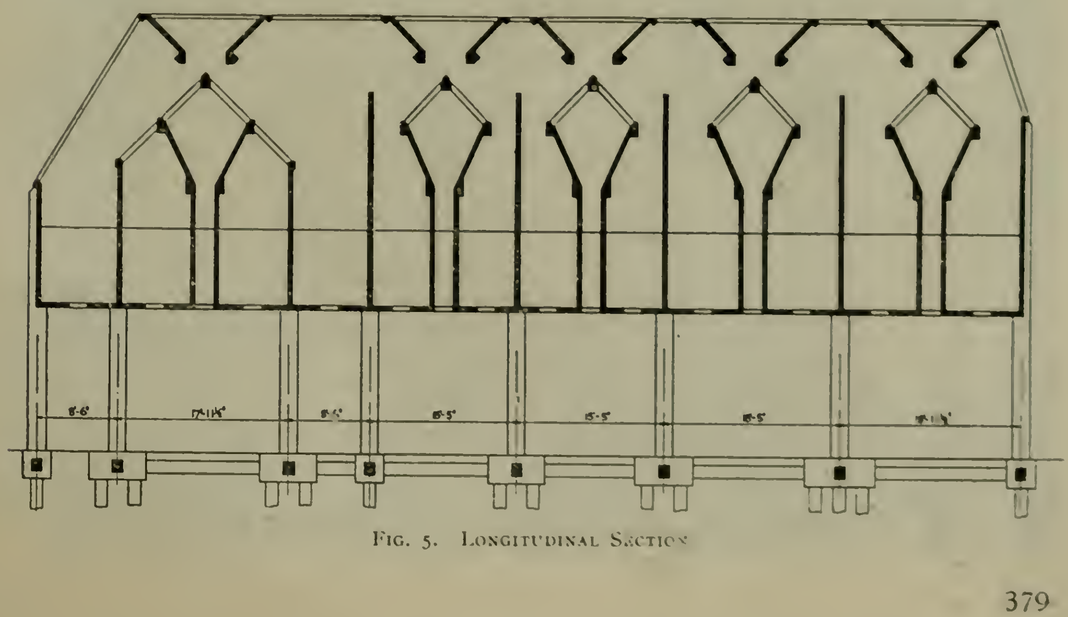


Fig. 5. Longitudinal Section

Fig. 7.

Fig. 6.

Reinforced Concrete at Greenbank Gasworks, Blackburn.

at proportionate radii. The crane rails are carried on timber longitudinal sleepers resting on 24 in. by 13 in. longitudinal concrete beams, forming the top booms of king trusses, 9 ft. 6 in. deep, spanning between the main columns. The vertical suspenders introduced take up the deflection on the long ties. Each pair of main columns is braced transversely (as shown in *Figs.* 7 and 8) in a vertical direction, and the bays, which are braced below the main trusses in a vertical direction, are also braced in a horizontal direction at the ground, at the intermediate level, and at the top. The 13 in. by 13 in. columns are carried by pile caps carried on 16-in. diameter piles braced longitudinally throughout, in addition to the diagonal bracing in the first and fourth bays.

A continuous platform 5 ft. wide is provided for the entire length on one side of the gantry, as shown in *Fig.* 5, supported upon cantilevers from the top boom of one of the trusses, and provided with the necessary handrailing and access ladders. In considering the rolling loads a suitable allowance was made for impact before determining working stresses. The effect of the timber cushions under the rails has been very beneficial in reducing vibration throughout the structure, which even under the most rigorous treatment has proved to be very slight, and is satisfactory in every way. Thorough provision is made for meeting the stresses due to acceleration and retardation of the travelling loads and for slewing and hoisting motions, and no weakness of any kind has appeared after six months' working. The crane serves to remove coke from the retort house to the main coke storage hoppers, from which it is either passed to railway wagons running below or to carts for local distribution.

The main storage hoppers have a total capacity of 250 tons of coke, and are divided into seventeen transverse self-clearing compartments, with openings in the bottom for delivery of coke into railway trucks, running on a track connected with the main gasworks sidings. In addition, eleven side shoots are pro-

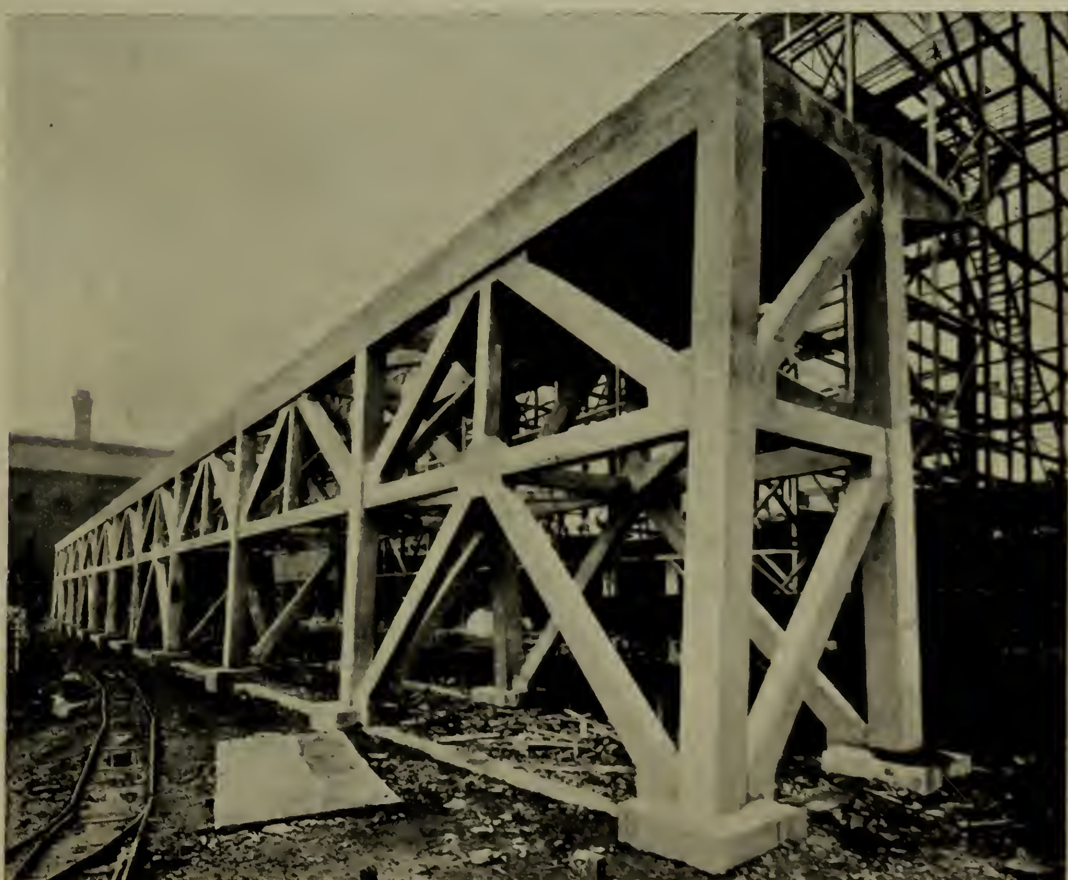


Fig. 8. Greenbank Gasworks, Blackburn.

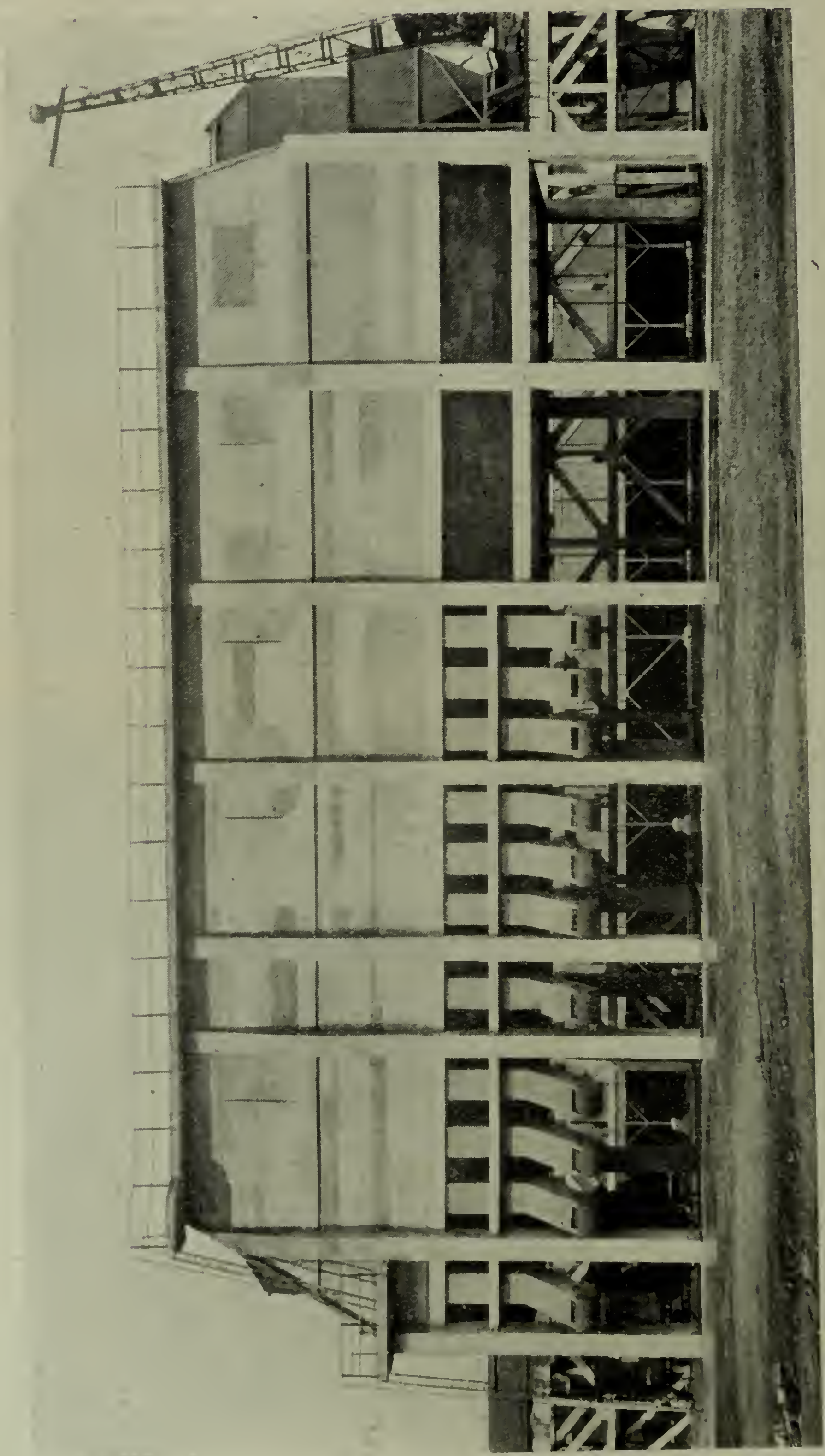


Fig. 9. Greenbank Gasworks, Blackburn.

vided on the site farthest away from the gantry for filling bags, carts, or motor-lorries for local distribution. *Fig.* 4 shows a typical cross section of the hoppers, and *Fig.* 5 shows a typical longitudinal section.

The coke dropped into the receiving hoppers is passed over fixed bar screens mounted on the tops of the hoppers, and the coke is screened and sorted entirely by mechanical handling ready for delivery into vehicles. The main columns, sixteen in number, are 30 in. by 22 in. in cross section in the case of the inside column, and 30 in. by 20 in. in the case of the outside columns, and are tapered towards the top as shown in *Figs.* 7, 9, and 10. The columns are carried on concrete caps, which in turn are supported by 16-in. diameter concrete piles to the total number of fifty-two, the caps being braced in both directions by longitudinal or transverse tie-beams 18 in. by 15 in. in cross section. The hoppers are 46 ft. high overall, 105 ft. long overall, and 19 ft. 6 in. wide overall. Upon one side the necessary concrete platform, handrailing and access ladders are provided.

The concrete in the coal-breaker pit was machine mixed in the proportions of 3 of crushed granite (¾ in. graded to ¼ in.), 1½ portions of screened sand, and 1 portion of "Ferrocrete" cement, by bulk; the concrete in the remainder of the work, including the piles, being in the proportions of approximately 4 : 2 : 1.

The whole of the reinforced concrete work was designed for Messrs. West's Gas Improvement Co., Ltd., by their Consulting Engineer, Mr. Burnard Geen, M.Inst.C.E., of 122 Victoria Street, Westminster, and was erected by Messrs. Simplex Concrete Piles, Ltd., of 104 Victoria Street, Westminster, S.W.1.

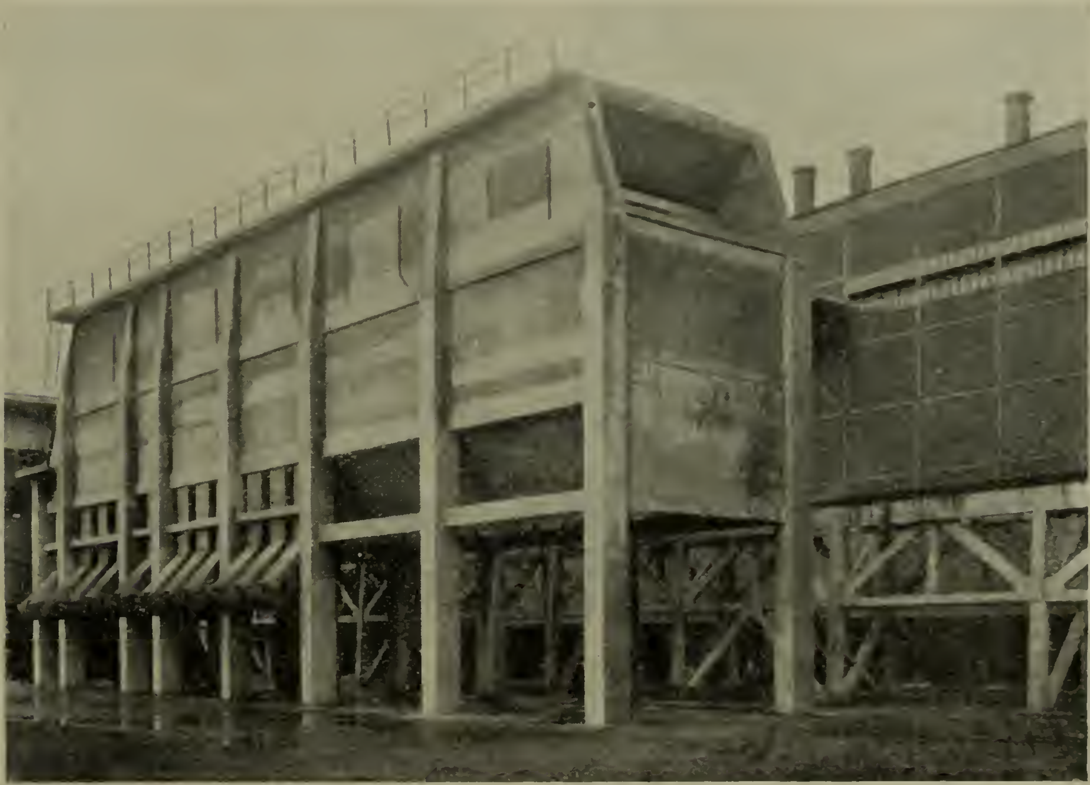


FIG. 10. GREENBANK GASWORKS, BLACKBURN.

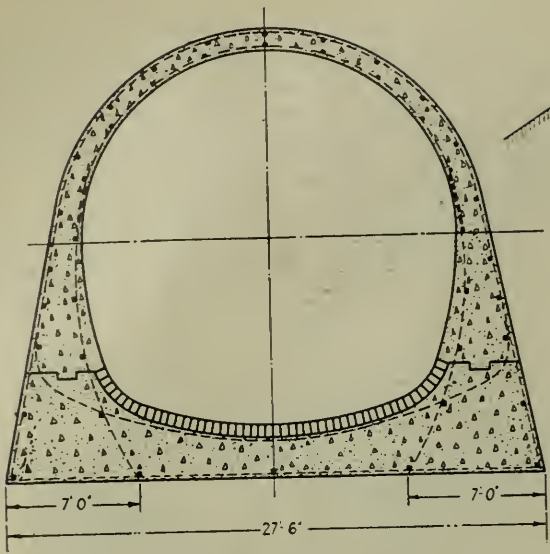
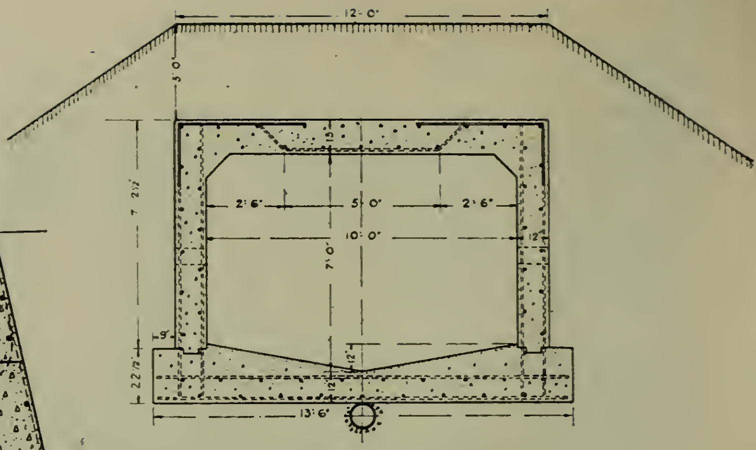
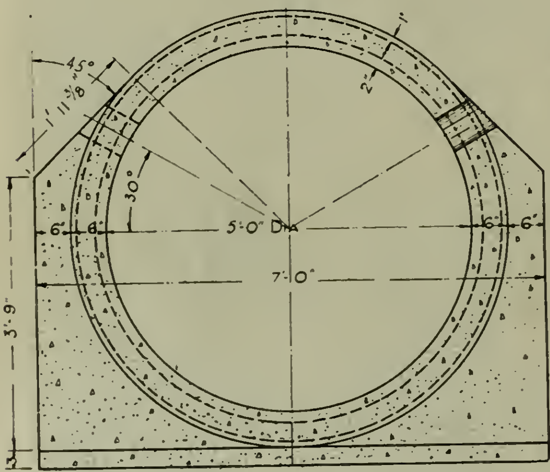


Fig. 23.



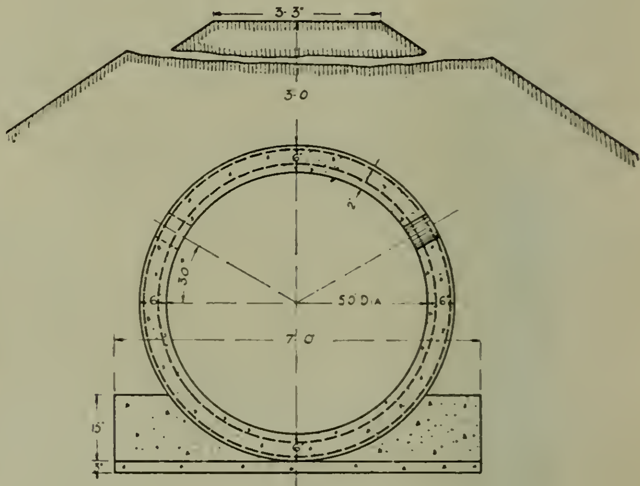
7'-0" x 10'-0" SECTION

Fig. 24.



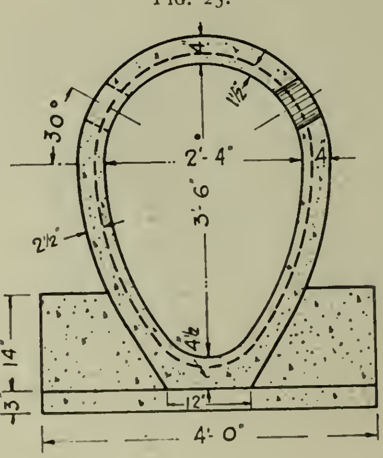
5'-0" SECTION UNDER RAILROAD

Fig. 25.



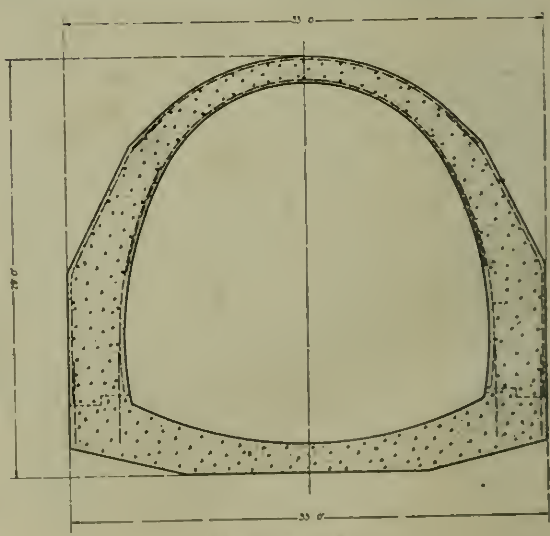
5'-0" SECTION

Fig. 26.



3'-6" x 2'-4" SECTION

Fig. 27.



25 FT SECTION

Fig. 28.

Reinforced Concrete Sewers in America (*see p.* 385).

REINFORCED CONCRETE SEWERS IN AMERICA.

By E. R. MATTHEWS, A.M.Inst.C.E., F.R.S. (Ed.), F.R.San.I.

(*Continued from page* 253.)

PHILADELPHIA.

No better examples of the use of reinforced concrete in the construction of large sewers could be found than those which have been constructed during recent years in Philadelphia. By the kindness of the City Engineer the author is able to illustrate in *Figs.* 20 to 22 sections through the main sewer in Bingham Street, between Adams Avenue and the Frankford Branch of the Philadelphia and Reading Railway. This sewer was approved in October, 1921, and the work is now in hand. Some of the sections indicate that the sewer has been constructed in earth, and others in tunnel. *Fig.* 20 represents a 7-ft. sewer in earth. It is surprising to find that at the centre of the crown of the arch the thickness is only 7 in. An earth embankment covers this sewer. The width of the base of the sewer is 13 ft. 3 in., and a subsoil drain (5 in. with open joints) is beneath. The arch is keyed at the springing line, and the thickness of the arch at this point is 1 ft. 5½ in. The invert of this sewer is not brick-lined, but is finished off to a smooth face by a 1½-in. rendering of granolithic.

Fig. 21 shows a similar section, but this is through a 6 ft. 6 in. sewer. The base in this case is 12 ft. 4 in. in width, the crown 6½ in. thick, and the thickness of the arch at springing is 1 ft. 4¼ in. There is 3 ft. of soil covering above the arch.

Fig. 22 represents a section into rock,

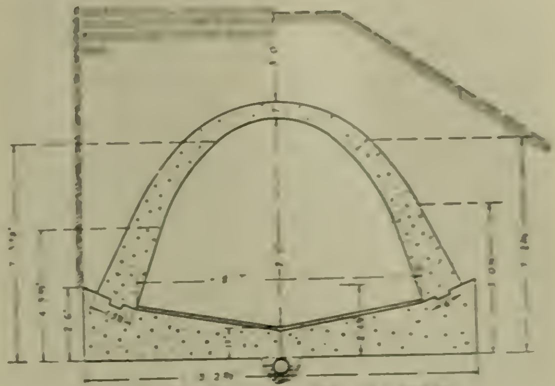


FIG. 20.

the sewer being covered with rubble masonry packing.

WING'S LOCKING SEWER IN HOWARD STREET.—*Fig.* 23 represents a sewer of unusual dimensions with no embankment. It is oval in shape, and has a brick-lined invert. It measures 19 ft. by 19 ft., and is reinforced by twisted steel rods, which occur on both the inside and the outside of the arch. The whole of the reinforcement has a covering of 2½ in. The longitudinal rods are 1 in. square, and are placed where shown in the section. The width of the base is 27 ft., and it is reinforced at the bottom. The arch is keyed into the foundation slab. The thickness of the sewer at the centre of the base is 2 ft.

MAIN SEWER IN PACKER STREET.—*Fig.* 24 illustrates a section through this sewer. Where the section was taken it is 10 ft. by 7 ft. (inside measurements).

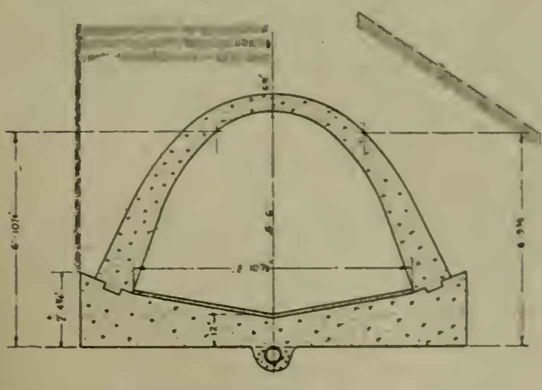


FIG. 21.

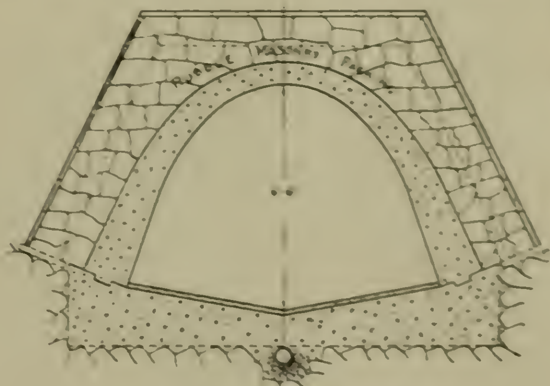


FIG. 22.

FIG. 29. DUKE'S DITCH, CHISWICK.
(Before construction of Culvert.)

and supports an embankment. The thickness of the roof slab is 13 in., the walls 12 in., and the centre of the floor slab 12 in. The floor slab is 13 ft. 6 in. wide, and a subsoil drain is laid under it. The reinforcement is shown in the section. The invert has a $1\frac{1}{2}$ in. granolithic finish. The vertical walls are reinforced inside and outside.

CIRCULAR SEWERS.—Circular sewers have been used a great deal in Philadelphia, and of all sizes; they have been used as pre-cast R.C. pipes, and also as monolithic structures. They are made of concrete composed of 1 part Portland cement, 2 parts sand, and 4 parts gravel or crushed stone. The concrete base is composed of 1 part Portland cement, 3 parts coarse sand or gravel, and 6 parts crushed stone. The author does not recommend that the proportions should be greater than 1 : 2 : 4, and if the pipes are to be under pressure at any time, he suggests that a 1 : $1\frac{1}{2}$: 3 mixture be used.

EGG-SHAPED SEWERS.—This shape sewer in reinforced concrete (pre-cast and monolithic) has also been used considerably in Philadelphia. *Figs.* 25 and 26 represent a 5-ft. circular main sewer in Moyamensing Avenue, (*a*) under railroad, and (*b*) under embankment. The arrangement of the reinforcement inside and outside is shown in these sections. In (*b*) the shell is 6 in. in thickness. The base slab is a maximum of 18 in. in thickness. *Fig.* 27 illustrates an egg-shape sewer 3 ft. 6 in. by 2 ft. 4 in. in size; this is a portion of the same sewer.

CHICAGO.

All local sewers in Chicago are built by the Board of Local Improvements under the direction of its Engineer, Mr. C. D. Hill. The sewage disposal works, including large intercepting sewers, are constructed by another municipality, the Sanitary District of Chicago, which includes Chicago and its environs. Concrete sewers are in general use in the Sanitary District. Mr. C. D. Hill informs the author that he is greatly in favour of using a reinforced sewer arch where very heavy definite loads are to be supported; he is, however, a little doubtful as regards deterioration of the concrete taking place in the invert unless it is lined with bricks.

About ten years ago the Corporation of Chicago built about fourteen miles of plain concrete sewers ranging in size from 4 ft. to 10 ft.; no reinforcement was used. The sewers were circular in section, and the engineer states that they have no trouble with them. The cost of these was practically the same as if built of brick.

Fig. 28 illustrates a 25 ft. typical section through the 39th Street conduit, constructed by the Sanitary District of Chicago. This is reinforced inside and outside by $\frac{7}{8}$ in. rods laid longitudinally and transversely as shown. The width of the base slab is 33 ft.

The author wishes to express his thanks to the City Engineers of the various American cities who have furnished him with so much useful information on this important subject, and to hope that British engineers carrying out important drainage works will adopt this method of construction as the cheapest, most reliable, and most permanent.

A BRITISH EXAMPLE.

Very few British examples can be found, but one of the best the writer has inspected recently is the Duke's Ditch reinforced culvert, Chiswick. This is being constructed for the Chiswick Urban District Council under the supervision of its Engineer, Mr. Edward Willis, M.Inst. C.E., and is illustrated in *Figs.* 29 to 34. The work is being carried out in a very efficient manner, and the design is excellent. This culvert has been introduced in order to carry off surface-water drainage from a large area, for storage purposes, and for feeding the Duke's Lake with tidal waters during the summer months. The length of the culvert is about one-third of a mile.

The section adopted is designed to give a deeper flow for the ordinary dry weather flow of surface water, and so avoid the deposit which usually occurs on a broad

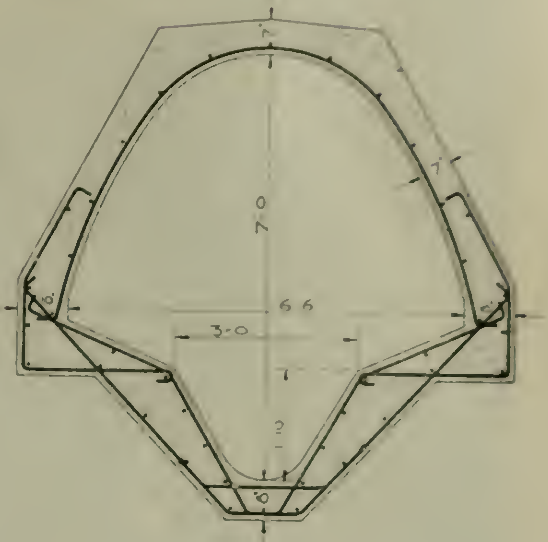
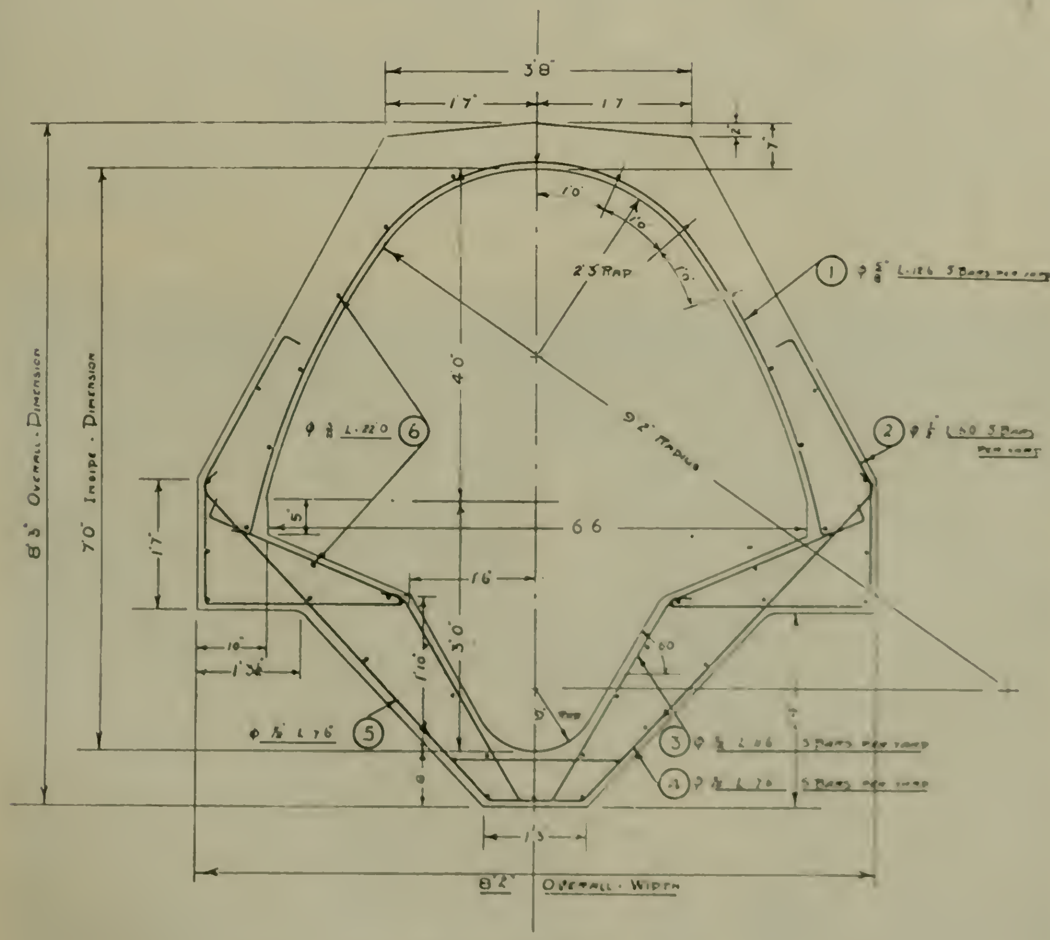


Fig. 30. Duke's Ditch Culvert.



Typical Cross Section.

Fig. 31. Duke's Ditch Culvert

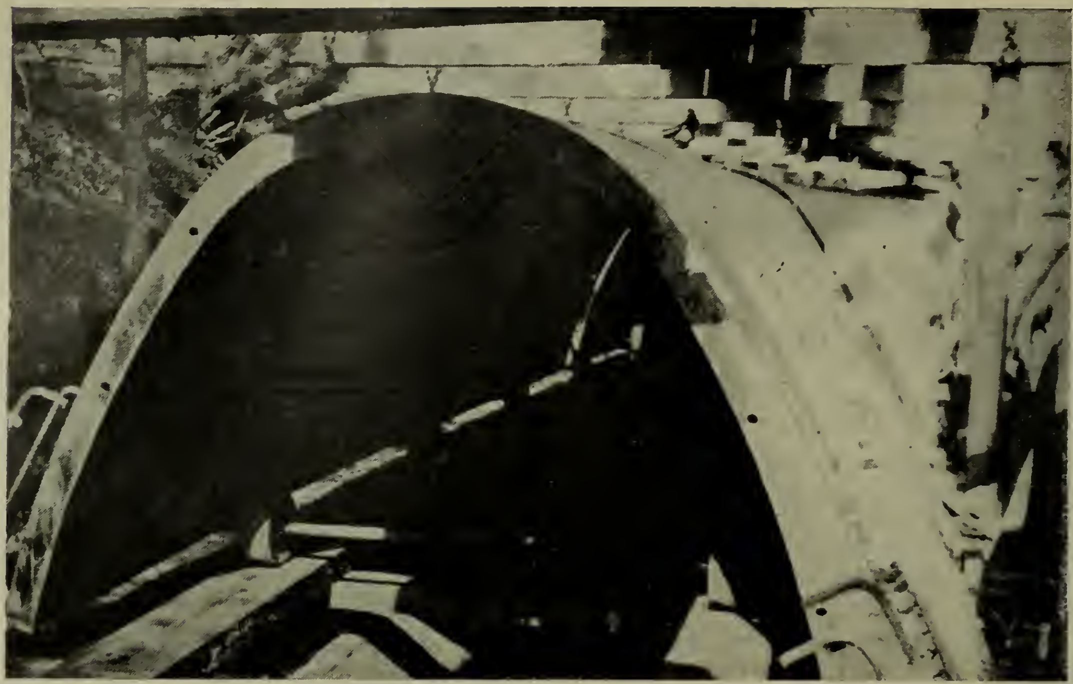
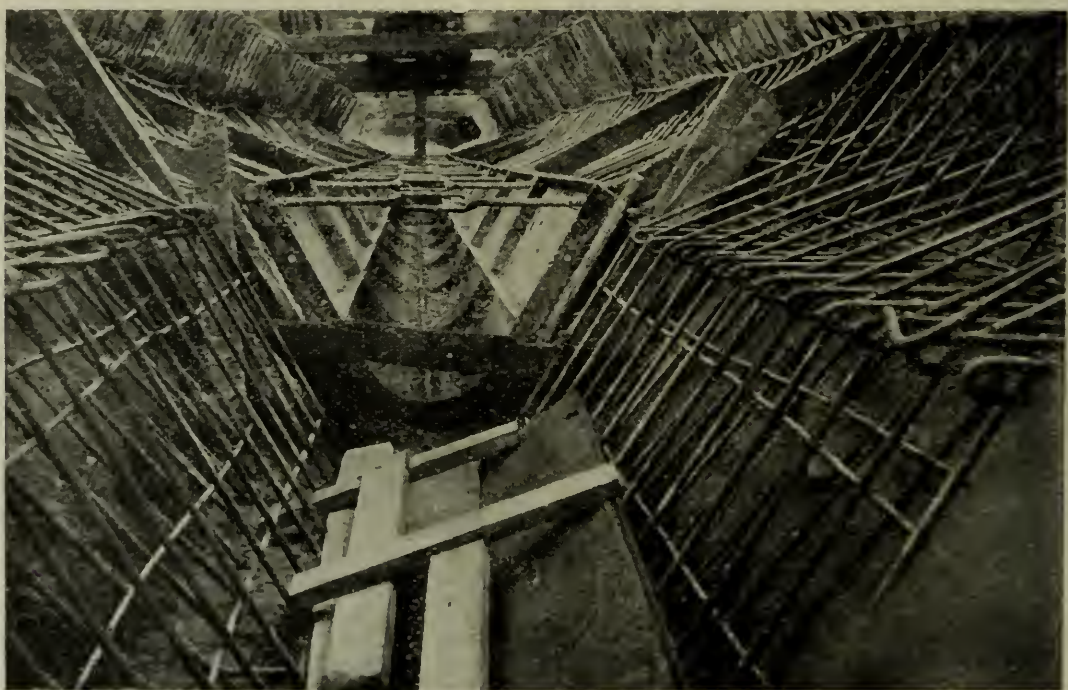


Fig. 32. Duke's Ditch Culvert, Steel forms used.

flat invert during normal flows, when the limited flow is insufficient to move it. The structure is 7 ft. high, and 6 ft. 6 in. wide, the roof being nearly in the form of a catenary arch. The area of the culvert is about 28 sq. ft., equivalent to a 6 ft. diameter barrel sewer, and the storage capacity is upwards of 300,000 gallons. Manholes are provided about every 100 yds. apart, and several penstocks have been introduced.

The reinforcement consists of $\frac{5}{8}$ in., $\frac{1}{2}$ in., and $\frac{3}{8}$ in. rods as shown on the section (*Fig.* 33). A test load is to be applied to the finished structure by two 10/15-ton rollers passing over it.



(Details of Reinforcement and Steel Forms.)
Fig. 33. Duke's Ditch Culvert.

Fig. 30 shows a section through this culvert. *Fig.* 29 illustrates the ditch before the construction of the conduit. *Fig.* 31 and 34 show the reinforcement and details of steel forms, and *Fig.* 32 the steel forms supporting the arch.

Collapsible steel forms for the invert and roof are a special feature in the construction of this conduit; these Blaw forms were supplied by Messrs. Christmas, Hulbert & Walters, Ltd., of Caxton House, Westminster, the sole British representatives of the Blaw-Knox Co., of U.S.A. The contractors for this work were Messrs. Peter Lind & Co., of Westminster; the clerk of works being Mr. E. O. Danger.

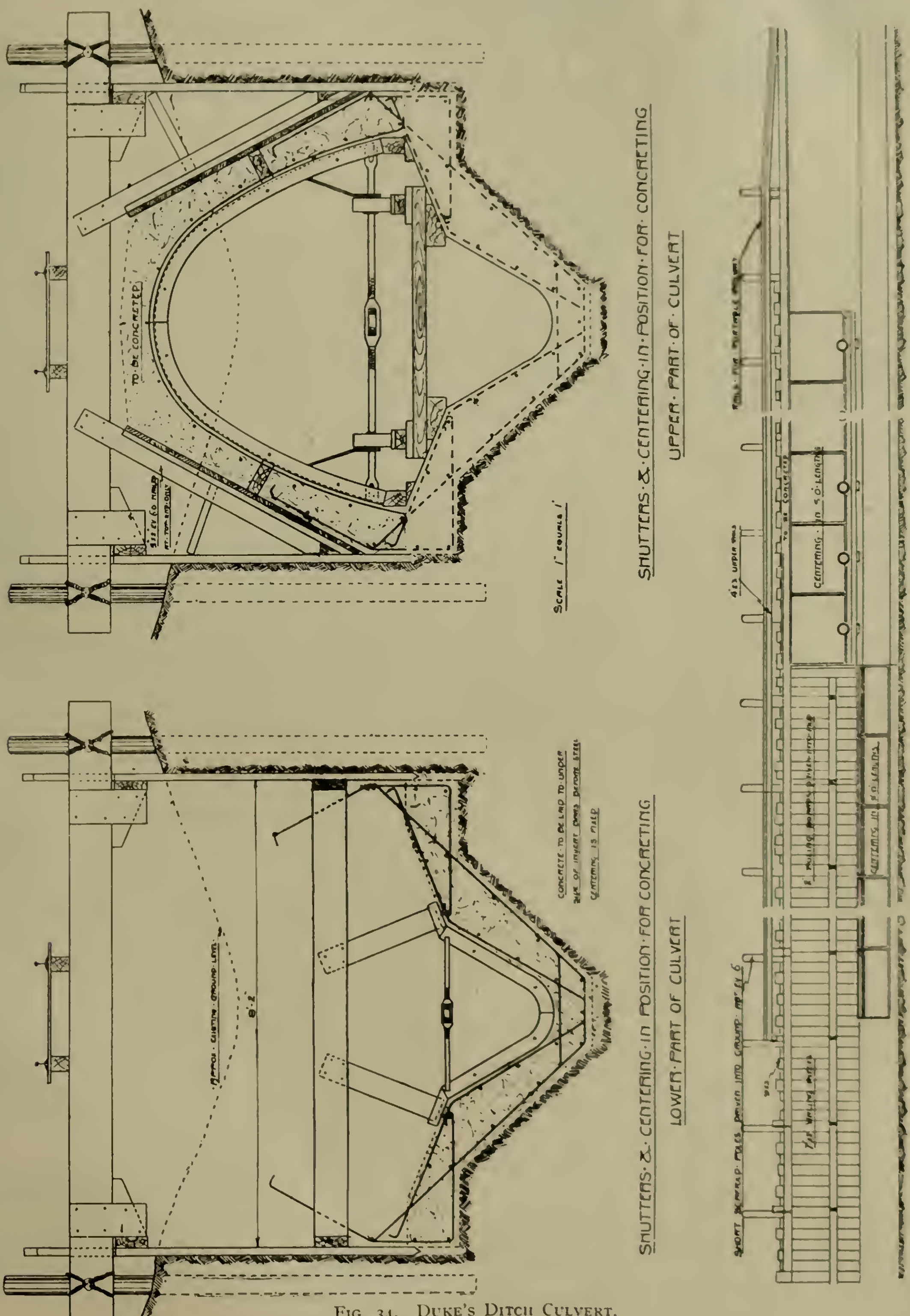
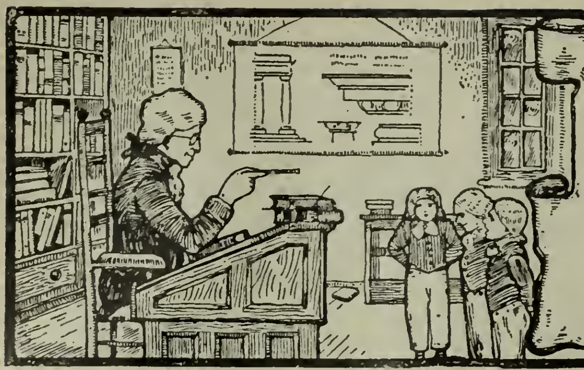


Fig. 34. Duke's Ditch Culvert.



SIMPLE EXAMPLES OF REINFORCED CONCRETE DESIGN.

(Continued from April.)

By OSCAR FABER, O.B.E., D.Sc.

Having now designed the secondary and main beams, we can turn to the columns and footings. It should, however, be noted that all the beams already calculated were beams continuous at both ends with beams in adjacent spans. Actually, however, only half the beams are continuous at both ends, the remainder being continuous at one end, but resting on a wall beam or a wall column at the other end.

The effect of continuity at both ends was to reduce the moment for which the beams were to be designed from $\frac{Wl}{8}$ to $\frac{Wl}{12}$. When continuous one end only, instead of two, only half this reduction should be made, namely, from $\frac{Wl}{8}$ to $\frac{Wl}{10}$. This will be done with sufficient accuracy by increasing the area of steel in all the end beams by multiplying the area in the interior beams by the fraction $\frac{12}{10}$, leaving the arrangement of bars the same. The shear is not substantially changed,* so this will meet all the requirements of the case.

COLUMNS.

There are really four types of columns, nine centre ones (*a*), six wall columns carrying one main beam and two secondary beams (*b*), six wall columns carrying two main beams and one secondary beam (*c*), and four corner columns (*d*).

Type (*a*).—This column clearly carries at each floor :—

2 main beam reactions of		lb.
	62,500 lb. =	125,000
2 secondary beam reactions of		
	31,250 lb. =	62,500
		187,500

As a check on this, the total load on each panel is clearly

$25' \times 25' \times 300$ lb./ft.² = 187,500 lb.

If there were no bending in the columns, or unequal loading of the floors, the columns would be designed for a concentric load of 187,500 lb. for the upper length and 375,000 lb. for the lower.

Stressing the columns to 600 lb./in.², this would require equivalent areas of

$\frac{187{,}500}{600} = 312$ sq. in. for the upper length

and $\frac{375{,}000}{600} = 624$ sq. in. for the lower length.

Referring to *Reinforced Concrete Simply Explained*, p. 53, it will be seen these areas are given approximately by standard 16 in. and 24 in. square columns respectively, having four 1-in. rods and eight 1-in. rods respectively.

It will, however, be interesting to see what stresses may be induced by bending of the beams when the panels on the two sides of any column are unequally loaded, the worst bending occurring when the main beam on one side is fully loaded and that on the other is subject to the dead load only.

Let us consider the upper length first and follow the treatment given in *Reinforced Concrete Simply Explained*, Chap. V. The load on the column, under these circumstances will, of course, be less, and will be as follows :—

* These approximations are essential to a "simple example." More accurate moment and sheer determinations are given in *Reinforced Concrete Design*, Vols. I and II.

	lb.
from the loaded main beam, as before	62,500
from the unloaded main beam, dead load only	20,833
from the two secondary beams, dead load	20,833
half live load	20,833
	125,000

In this calculation it is assumed that of the total load of 300 lb. per sq. ft., one-third is dead load (i.e., weight of slab and beams, etc.), and the remainder live load. This gives a dead load of 100 lb. per sq. ft., which can be checked with the weight of the slab and beams already calculated, and found to be practically correct.

The two secondary beams will carry only half the usual live load, as they will only be loaded on one side (i.e., towards the loaded main beam) and unloaded on the other.

The actual direct stress due to the load is therefore only

$$\frac{125,000}{300} = 416 \text{ lb./in.}^2,$$

300 being the equivalent area of the standard 16 × 16 column (see *R.C.S.E.*, p. 53).

Coming now to the stress due to bending, the moment of inertia of the main beam (standard 30 in. × 12 in. T beam) is 78,000 in.⁴ (see *R.C.S.E.*, p. 35) and its length (or span) 25 ft., while the moment of inertia of the standard 16-in. square column (*R.C.S.E.*, p. 53) is 7,090 in.⁴ and its length $12\frac{1}{2}$ ft.

F_p, the fixity factor for an interior column may be taken as 4 (*R.C.S.E.*, p. 55),

$$\text{whence } \frac{F_p \cdot S_p}{S_b} = 4 \times \frac{\frac{7,090}{12\frac{1}{2}}}{\frac{78,000}{25}} = \cdot 73$$

Referring to Table III (*R.C.S.E.*, p. 55), it will be seen that the corresponding moment in the pillar is about midway between

$$\frac{Wl}{117} \text{ and } \frac{Wl}{60}, \text{ say } \frac{Wl}{88}$$

where *W* is the *live* load on the beam and *l* the span

$$\text{So that } B = \frac{Wl}{88} = \frac{41,666 \text{ lb.} \times 300 \text{ in.}}{88}$$
$$= 142,000 \text{ in. lb.}$$

This needs to be multiplied by $\frac{12}{9}$ owing to third point loading instead of uniform for which Table III, *R.C.S.E.*, p. 55, was prepared, giving,

$$B = \frac{12}{9} \times 142,000 = 188,000 \text{ in. lb.}$$

$$C = \frac{Bd}{2I} \text{ (see } R.C.S.E.)$$
$$= \frac{188,000 \times 16 \text{ in.}}{2 \times 7,090}$$
$$= 213 \text{ lb./in.}^2$$

Hence, the maximum stress is
416 direct + 213 bending =
629 lb./in.² total.

The bending in the lower length of column may occur with the upper floor fully loaded, and the lower floor loaded on one side only, as before, in which case the load on the column will be

	lb.
load from upper floor (as before)	187,500
,, ,, lower floor (as before)	125,000
Total	312,500

$$\text{Direct stress} = \frac{312,500}{664} = 470 \text{ lb./in.}^2$$

664 being the equivalent area of the 24-in. square standard column (*R.C.S.E.*, p. 53).

In this case the bending of the beam in first floor causes bending in, and is therefore resisted by, both the upper and lower lengths of pillars, the stiffnesses of which are therefore to be added.

$$S_p \text{ (upper length)} = \frac{7,090}{12\frac{1}{2}} = 566$$
$$S_p \text{ (lower length)} = \frac{34,000}{12\frac{1}{2}} = 2,733$$
$$S_p \text{ (total)} = 3,300$$

34,000 being the moment of inertia of the 24-in. square standard pillar (see *R.C.S.E.*, p. 53).

$$\text{therefore } \frac{F_p \cdot S_p}{S_b} = \frac{4 \times 3,300}{\frac{78,000}{25}}$$
$$= 4 \cdot 25$$

whence the bending moment in the pillar is about $\frac{Wl}{25}$ (*R.C.S.E.*, p. 55)

$$B = \frac{Wl}{25} = \frac{41,666 \times 300}{25} = 500,000 \text{ in. lb.}$$

This again needs multiplying by $\frac{12}{9}$ to allow for third point loading, and gives

B = 667,000 in. lb. This moment needs to be divided between the upper and lower lengths of pillar in proportion to their stiffnesses (S_p), that in the lower length being

$$667{,}000 \times \frac{2{,}733}{3{,}300} = 546{,}000 \text{ in. lb.}$$

and the stress due to it being

$$C = \frac{Bd}{2I} = \frac{546{,}000 \times 24 \text{ in.}}{2 \times 34{,}000} = 193 \text{ lb./in.}^2$$

Whence maximum stress is

$$C = 470 \text{ direct} + 193 \text{ bending} = 663 \text{ lb./in.}^2 \text{ total.}$$

It will be seen from these calculations that the interior columns are stressed to about the same figure whether they are fully loaded (in which case there is no bending in them) or loaded from one side only, in which case the load is eccentric and produces bending stresses (the latter giving slightly greater results). It may, in fact, be conceded that in general interior columns need only be designed for the simple case of full load and concentric stress distribution when the arrangement is a symmetrical one. Nevertheless, the calculation was thought to be worth making in this instance to exemplify the correct method and to prove this fact.

It must also be remembered that the writer is disposed to allow a considerable raising of permissible stresses when secondary bending is fully taken into account (see *R.C.S.E.*, par. 72, pp. 58–59).

In outside pillars, however, the case is quite different. Bending occurs when the pillar is fully loaded, and the bending stress is not therefore offset by a corresponding reduction in direct stress. The bending stresses are also much higher. For both these reasons, it is essential that allowance for bending be made for outside pillars and that such pillars be made larger than if designed for direct stress only.

(*To be continued.*)

OIL-CONTAINERS AND TANKS OF CONCRETE.

MUCH of the information which has been published on the use of concrete tanks for containing various kinds of oil is of too general a character to be of much technical value, and, consequently, there have been placed on the market a considerable number of "oil-proofing materials," for which great claims are made.

As a matter of fact, it has long been known that mineral oils—including the different varieties of petroleum—do not attack Portland cement appreciably, and any well-made concrete tank which has been faced internally with a suitable cement-sand mortar serves perfectly well for the storage of mineral oils. The Report of the Association of German Portland Cement Manufacturers published in 1892 showed that a rich cement mortar is wholly resistant to petroleum oil. The results of an investigation published in the *Engineering News Record* in 1919 also show that a well-made concrete is wholly unaffected by mineral oils. The German Admiralty have also found from tests extending over a year, that concrete tanks which have been washed over with water-glass are completely resistant to petroleum oils, and the experience of many users fully confirms these tests.

It is, of course, necessary that the tanks shall be well-designed and properly built by skilled men. They should be of medium size, as very large tanks are more resistant to the influence of the supports, changes in temperature, etc., and more readily crack and so leak.

The best shape of tank, for economical and mechanical reasons, is the cylindrical one with a flat top. The concrete should be of good quality, but special attention should be paid to the interior grouting or "plaster." This should be made of equal measures of Portland cement and sand thoroughly mixed in the dry state and afterwards with water. The grouting should be well rubbed into the concrete and finished as smoothly as possible. The addition of "fluates" or saline solutions, "Inertol," water-glass, etc., is usually satisfactory, but rather as a precaution than a necessity. —Abstract of an article by Dr. A. Feuchthaendler in *Tonindustrie Zeitung*, 1921, p. 1273.

SOME CAUSES OF CRACKING AND DISINTEGRATION OF PORTLAND CEMENT CONCRETE.

By R. E. STRADLING, M.Sc., A.M.Inst.CE., A.M.Am.Soc.C.E.

(Lecturer in Civil Engineering, Birmingham University.)

The reasons for the cracks and even disintegration which sometimes occur both during construction and some considerable time after completion are undoubtedly very numerous, not at all well defined, and in many instances not understood. The writer in this article endeavours to group together under general headings some of these with the hope of clearing a little the outlook into this problem.

The causes of cracking can, in general terms, be considered to be due to either (*a*) some property of one or more of the constituents of concrete, or (*b*) some property of the resulting concrete considered as a whole. Hence the causes considered are placed under four groups, as follows :—

(I) Those due to the composition and physical state of the cement as received on the site of the work.

(II) Those due to the misuse of the cement.

(III) Those due to the composition and physical state of the aggregate used with the cement to form concrete.

(IV) Those due to the conditions to which the concrete is exposed.

Now to consider these in detail and in the order stated above.

I.—CRACKS DUE TO THE COMPOSITION AND PHYSICAL STATE OF THE CEMENT AS RECEIVED ON THE SITE OF THE WORK.

It is necessary to realise clearly that the causes summarised under this heading do not apply to cements which pass the British Standard Specification in all tests.

To follow the reasoning submitted it is necessary to consider shortly the manufacture and chemistry of Portland cement. Portland cement consists essentially of lime (CaO), silica (SiO_2), and alumina, (Al_2O_3) combined together to form definite compounds held in solid solution. The compounds actually formed depend upon two general conditions, (i) the temperature of burning, and (ii) proportions in which the raw materials are mixed, and the "impurities" present.

The resulting products after the heating in the kiln are essentially :—

Tricalcium silicate $3CaO\ SiO_2$.
Bicalcium silicate $2CaO{\cdot}SiO_2$.
Tricalcium aluminate $3CaO{\cdot}Al_2O_3$.
Calcium silicate $CaO{\cdot}SiO_2$.

The last of these is inert so far as is known. There are various other compounds present, e.g., magnesia, ferric oxide, compounds of sulphur, etc., all of which may be considered to be impurities. The working temperature of a cement kiln is 1,300–1,500° C. ; if the temperature is not high enough or the wrong proportions are used the clinker formed will contain a certain amount of lime (CaO)—and also probably magnesia (MgO)—which has not combined with either silica or alumina but has been raised above 1,200° C., i.e., is "dead burnt."

It is necessary now to consider shortly the slaking of lime. If a "fat" lime (pure calcium oxide) which has been calcined at normal temperatures (800–1,000° C.) is slaked by the addition of water it crumbles, rises considerably in temperature and forms calcium hydrate or slacked lime. This action takes place almost instantly. With a "leaner" lime (i.e., one containing CaO + silica and alumina) calcined at the same temperature the same action takes place on the addition of water, but at a much slower rate.

If a lime is burnt at a higher temperature than 1,200° C. a state is reached at which it is extremely difficult to bring about the slaking. In the mass it will apparently resist hydration for very long periods, probably years. When finely ground, however, the hydration can be brought about more quickly, in fact sometimes with explosive violence.

To return to the consideration of Portland cement, we have seen that under certain conditions of manufacture it is possible to obtain "dead burnt" lime in a free state, also that it is probably not pure calcium oxide. Hence a compound is present which can resist hydration at the time of mixing the concrete (containing the cement) with water, but which, after a sufficient lapse of time, probably long after the concrete has set, is capable of combining with water with considerable expansion. The period of time which is required to enable the lime to reach this state depends upon the fineness of grinding. Hence the finer a cement is ground the shorter the time required, and with very fine grinding the action might take place before the concrete has taken its initial set, and thus cause no damage. If, however, the cement is comparatively coarse and the concrete is kept dry (e.g., in workshop floors) for a long period, perhaps for years, and then suddenly made very wet, it is quite conceivable that expansion due to this cause may take place. The writer has just received a specimen from a concrete floor which after twenty-seven years in position was suddenly exposed to a heavy storm of rain during some structural alterations to the roof of the building. The floor expanded sufficiently to push out the enclosing walls, causing their collapse. It is not possible to say definitely to what cause this failure can be attributed, but it was of such a nature as to take place suddenly after twenty-seven years when exposed to water after a long period in a dry atmosphere. The " dead burnt " lime theory would account for this, but, as will be seen later, it is not certain that the lime came from the cement. A very similar action can be obtained with magnesia (MgO), as the " dead burnt " variety is extremely difficult to hydrate.

To turn now to another substance which may cause disintegration—the sulphur. This is present in two forms, as a sulphide or as a sulphate. It is not at all clearly understood what exactly is the action which causes failures usually attributed to sulphur compounds. From the writer's experience he knows that abnormal percentages of gypsum present in a cement will cause failure, but what the action is it is difficult to say. Under certain conditions sulphate, lime, and alumina will combine to form the calcium sulpho-aluminate which crystallises into small needle-like forms. An illustration of these is shown in *Fig.* 1. It is conceivable that the formation of these crystals in a porous mass like concrete might cause disintegration by the forcing apart of particles of stone and cement by the growth of the needles, but so far as the work of the writer has gone in this direction only negative results have been obtained. The example shown in *Fig.* 1 has been cultivated artificially—it has been taken from the work of Mr. R. J. Colony (Columbia University). Although the writer has examined a large number of specimens of concrete containing high percentages of gypsum (up to 10 per cent. of the cement used) which have disintegrated in the mass, yet these crystals have not been discovered, though, of course, this result may be due to the imperfection of the methods used in the investigation. The experimental fact remains clear—high percentages of gypsum cause failure due to disintegration and lower percentages weaken the strength of cement compounds.

Fig. 1. Supposed Calcium Sulpho-aluminate Crystals.

In some experiments carried out by Professor F. C. Lea and the writer it has been shown that the strengths of cement, mortar, and concrete are all reduced by the addition of high percentages of gypsum, and that disintegration occurs with the greater additions (above 8 per cent. added gypsum). One interesting point brought out by the experiments was the failure of the " Le Chatelier " test to show any unsoundness in the cements. The writer is definitely of opinion that the " Le Chatelier " test, though of great value in the detection of probable expansions when due to certain causes (" dead-burnt " lime and coarse grinding), does not give any indication of probable failure due to excess of sulphur in the form of gypsum. The failure due to sulphur appears to require time, and is not hastened by heating in boiling water. This seems to indicate that the cause of the failure is due to the formation of crystals, and hence to indicate some such action as the calcium sulpho-aluminate theory. The action is not clear, and requires much further work entailing the close co-operation of chemist and engineer.

The other form in which the sulphur might be present is that of a sulphide. Here again so little is known as to the actions possible that no positive theory can be stated. If calcium sulphide is present and also iron in the ferrous state then the green ferrous sulphide is formed, which is liable to oxidation accompanied by an expansion of volume. Usually the sulphide is more likely to occur in a slag than in a cement, but it is found, and especially in one made by the stationary kiln process.

Quite apart from these chemical considerations the actual physical state of a cement has a great effect on its liability to expansion or otherwise.

The table shown in *Fig.* 2, taken from a paper by Mr. A. C. Davis (*Proc.* I.C.E., CLXXV), is of great importance. The

	Period of Aeration.					
	Fresh	7 Days.	14 Days.	21 Days.	28 Days.	35 Days
Rotary-kiln cement .	mm 2·0	mm. 1·5	mm. 1·5	mm 1·5	mm. 1·25	mm. 2·0
Residue on 180 × 180	25·25	22·5	23·5	24·0	21·5	24·0
Cement through 180 × 180 .	4·5	3·75	2·0	1·75	3·0	3·0
Grit from flourometer	38·75	43·5	41·0	39·0	37·5	36·0
Flour from flourometer	2·25	1·5	1·25	2·5	1·75	2·0
Ordinary kiln cement	3·5	2·0	2·5	2·25	3·5	3·5
Residue on 180 × 180	23·75	20·25	24·25	21·5	27·0	23·0
Cement through 180 × 180	2·75	2·25	1·0	2·5	1·0	1·0
Grit from flourometer	21·0	20·0	18·5	12·5	9·0	7·0
Flour from flourometer . . .	1·0	1·5	1·0	1·75	2·75	2·0

FIG. 2. TABLE SHOWING THE EXPANSIONS, REGISTERED BY THE CHATELIER APPARATUS, OF VARIOUS SIZE GRAINS OF PORTLAND CEMENT.

effect of fineness of grinding on the expansion of the cement is well shown. It seems probable that only the very finest of the particles are really useful in a cement. The grains referred to are those separated by an air analyser, for, as will be seen, the particles passing the 180 by 180 sieve and left behind by the air analyser are the chief sources of expansion.

The general theory of this type of expansion seems to be that with a moderate-sized particle the outer layers become hydrated at once in mixing and form a coating which obstructs the passage of water to the interior. This interior only hydrates with extreme slowness. In fact, after many years very little increase in the hydration of these particles can be observed by the microscope even when the samples have been stored under water.

It appears quite to be expected that under the effect of boiling water these larger particles should become hydrated, due to the increased power of penetration possessed by hot water caused by the decrease in surface tension. It does not seem so obvious that a similar effect can be produced by time alone; in any case the expansion would be gradual, and not sudden. With a porous material like concrete it is reasonable to suppose that water can reach the cement particles fairly easily, but, as stated above, it does not appear very probable that even after long periods there is much penetration into the central unhydrated portion of the cement grains.

There is one point in this connection, however, which may be suggested. If by some other action a splitting action is started it seems quite likely that unhydrated surfaces may become exposed to the action of moisture, and so carry the cracking a little further. The writer would submit for consideration in relation to the hot water ("Le Chatelier," or "pat") test for soundness of Portland cement, three suggestions really detailed above but put into definite form as follows :—

That this test :—

(1) detects probable expansion due to "dead burnt" lime or magnesia ;

(2) fails to detect any possible expansion due to sulphur present as gypsum ; and

(3) probably exaggerates the danger of the effect of coarse grinding.

It is worth noting that these considerations also indicate that the present methods of measuring the fineness of cement are only very approximate. The really useful particles are much smaller than those detected by the 180 by 180 sieve. A type of air analyser seems very necessary as a means of carrying out this test scientifically.

II.—FAILURES DUE TO MISUSE OF THE CEMENT.

Under this heading are included all those causes which can be attributed to bad workmanship, taking this word in its fullest meaning, and considering the cement only. It is convenient to consider these causes under three headings: those concerned with

(*a*) The setting time of the cement and amount of water used.

(*b*) Relative proportion of cement used.

(*c*) The methods of casting.

(*a*) Setting Time Problems and Amount of Mixing Water used.

As already pointed out, Portland cement consists of a number of different compounds (probably in solid solution) of fairly definite composition. From the work carried out in the Laboratory of the Bureau of Standards, Washington, U.S.A., it seems fairly well established that these compounds behave very differently from each other in their hydration reactions.

For the purposes of this discussion it is only necessary to discuss three of these. From the work of Kleine and Phillips and Bates and Kleine the following data is taken.

The first compound to hydrate is the tricalcium aluminate; this reaction starts practically as soon as the water is added. Very little strength is developed by this compound, and the duration of the period of hydration varies from a few minutes to a few hours.

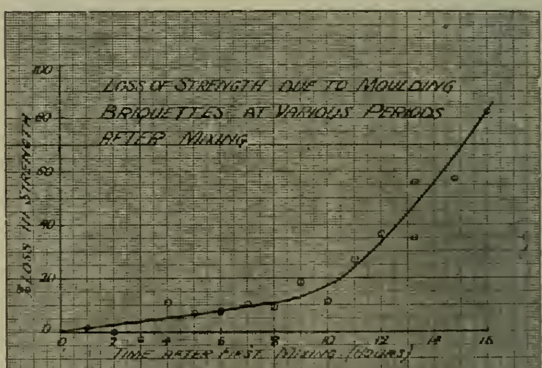
The next reaction is the hydration of tricalcium silicate, which commences after a period varying from minutes to a few hours and appears fairly well complete at the end of seven to twenty-eight days.

The third compound to hydrate is the dicalcium silicate, which though practically inert towards water in the pure state yet in the presence of certain aluminates slowly reacts and gives the hardening effect observed in Portland cement after long periods.

The second of these reactions is the important one from the engineer's standpoint. It is the tricalcium silicate which forms the compounds which give the cement its strength within the periods required in practice. The quick-setting of the tricalcium aluminate sometimes interferes with the hydration of the other compounds to an injurious degree. It is possible with some cements to get an increase in strength by remixing after the first set has taken place. This really means getting more of the tricalcium silicate hydrated at the expense of destroying the set of the tricalcium aluminate, and as the latter is much weaker than the former the result is a net gain in strength. This remixing is attended by a great many risks. If the silicate is rather quicker setting than anticipated, this will be interfered with, and thus a net loss in strength will result. The initial and final sets as registered by the Vicat needle are only arbitrary points. As pointed out by Professor Gary, there is a marked rise in temperature in a cement specimen at or after the final set.

The writer has carried out a few experiments in this direction by means of a Cambridge "Thermograph." This is essentially an automatic temperature recorder dependent upon the changes in pressure of an enclosed volume of mercury when subjected to changes in temperature. In *Figs.* 3 and 4 * are two curves which are closely related. A

Fig. 3.



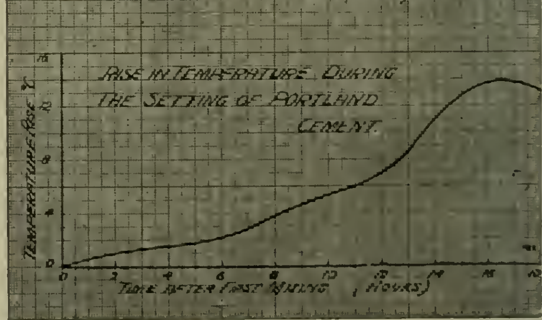


Fig. 4.

* The data for these curves was obtained for the writer by Messrs. Earle and Lawson, both students in the Civil Engineering Department, Birmingham University.

sample of cement ("Ferrocrete") was mixed with 22 per cent. water and specimens made as follows :—

(1) About 1,000 grms. of the mixture was used for recording the rise in temperature on setting, and the curve obtained (replotted to a horizontal scale) is shown in *Fig.* 4.

(2) Three tension briquettes were made up at the same time from the same mix and at 1 hour intervals other sets of three briquettes were made—all from the same mix and without any further addition of water.

At the age of seven days these briquettes were broken in a cement tester and the results are shown on *Fig.* 3. It will be seen how the two curves follow each other. This brings out very clearly the danger of disturbing a mixed cement during the process of setting, and the results bear very little relation to the setting time as registered by the Vicat needle. The initial set by the latter occurred at thirty minutes from completion of mixing, and the final set at four hours. The big temperature rise shown occurred at eighteen hours after mixing.

It is suggested that in concrete, where a much larger proportion of water is used, this "temperature rise" of magnitude will occur after even a longer period. Hence the absolute need for preventing the disturbance of concrete for many hours after once it is placed cannot be too strongly advocated.

The writer does not intend to indicate by this that disturbance necessarily means the cracking of the concrete, unless carried to a degree of violence not usual in practice, but he does submit that a concrete weakened in this way is much more likely to disintegrate by the contraction effects, etc., discussed later.

Anything which interferes with the setting process, preventing the "knitting" together of the hydrated particles, will cause disintegration. There are many things which will do this quite apart from the mechanical action of vibration, etc. A large excess of water is a common cause, also low temperatures. Though these two in themselves do not generally cause complete disintegration, they very often give the opportunity to other things. That excess of mixing water has quite a material effect on the final strength of a cement or mortar (and therefore concrete) is shown

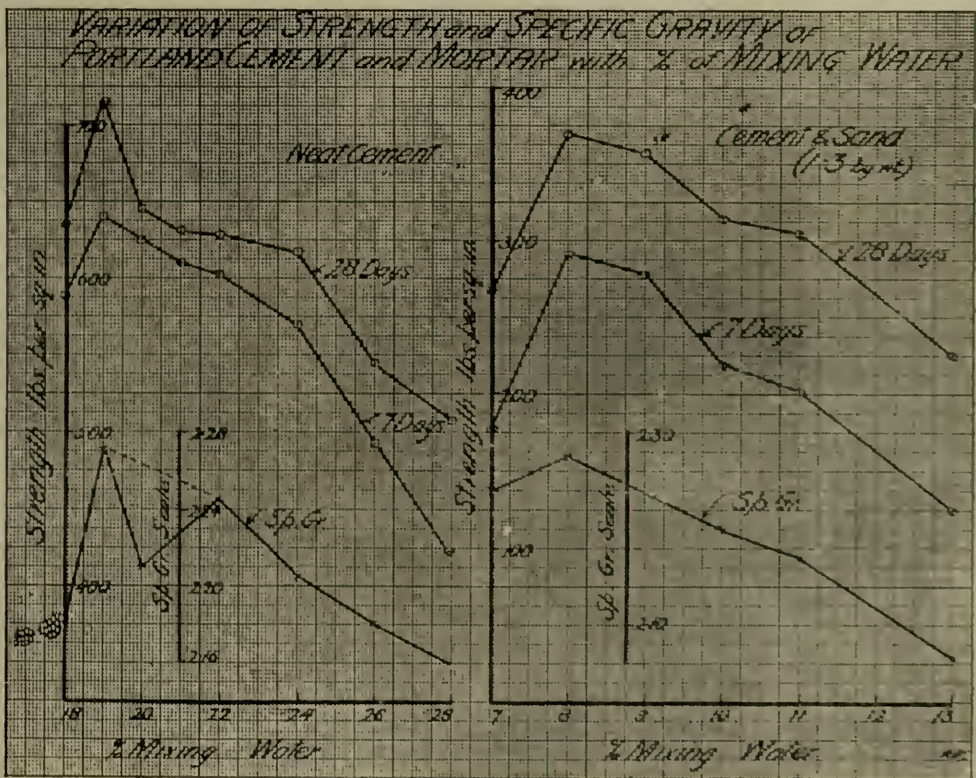


Fig. 5.

in *Fig.* 5.* The weakening is apparently partly due to defective hydration and partly to the suspension of the particles of cement in the mixing water, thus preventing them from getting into the close contact to which they might otherwise attain.

The interference with the setting of a cement by vibration or by the other means mentioned above is only, then, in itself a contributory cause, but the writer submits probably one of the primary reasons for failures in practice.

(*b*) Relative Proportion of Cement used.

If neat cement sets in air comparatively large contractions take place, these being of the order of 0·6 per cent. linear.† Thus, if the ends of a bar were held fixed and the cement did not break a stress of the order of 9,000 lb. per sq. in. would be the result (assuming $E = 1{\cdot}5 \times 10^6$). Such a stress is beyond the bounds of possibility, and contraction cracks result. If cement mortar is used the contraction on setting is very much reduced owing to the presence of the sand. In concrete this is still further reduced, but is still appreciable. The order of these contractions will be discussed later. We see, then, that the richer the mix the more the contraction. A neat cement rendering to a water tank, for example, is extremely difficult to apply, and even a 1 to 1 mix requires to be put on in comparatively small sections. This consideration leads us to the last sub-heading in this division.

(*c*) Methods of Casting.

If plain slabs of concrete without any steel reinforcement are laid down, say, as floors, it is very necessary that only small areas shall be cast at once. If this is not done cracking is practically certain to occur. In one case which came to the notice of the writer recently a floor had to be laid in two layers in very large slabs. The under layer was a fairly dry concrete with very little fine material; the upper layer was composed of a much finer grade, but laid down in slabs of about 50 ft. by 20 ft. After setting, the floor sounded extremely hollow all round the edges of this slab. The edges had cracked away from the surrounding slabs and the whole slab had contracted towards the centre without breaking in itself; the under layer was so "crumbly," due to the want of fine material, that it had disintegrated and allowed the upper layer to move relative to it. It may be questioned why this case is quoted under the heading of the misuse of cement. The writer would point out in this connection that it is the cement which contracts, causing the whole mass to do likewise, and hence it is the disregarding of one of the properties of cement which causes the cracking.

(*To be concluded.*)

* The data for this curve was obtained by Messrs. More and Robins, students in the Civil Engineering Department, Birmingham University.

† Dr. J. W. Mellor gives 1·18 per cent. as the value for this (see *Clay and Pottery Industries*, p. 81).

RENOVATIONS IN CONCRETE.

An interesting case of renovation with important alterations in which concrete proved particularly useful was carried out at the Town Hall, Burgdorf. The ground floor of the Town Hall was built of sandstone, the walls being 3 ft. 6 in. thick. On this were superimposed heavy transverse arches and the upper walls—all of brickwork. The ground floor had been used for stables and, in consequence, the lower portion of the walls was in a bad state, the mortar being reduced almost to sand, much of which had fallen out, so that in several parts the joints gaped to a depth of 20–30 in. The walls were badly attacked by the vapours and the arches had cracked in several places. Not only was the wall a source of danger, but it was also desired to make a series of large window openings in it. To renovate the structure and make the desired alterations at the same time, it was decided to cut into the masonry a series of dovetailed slots, each 22 in. deep, and to fill these with a series of reinforced concrete buttresses. The required window-openings were then cut between the buttresses and the foundation was strengthened by an additional concrete footing. The face of the building was then covered with concrete so as to give it a finished appearance. The alterations were designed by, and carried out under, the supervision of Architect Bechstein of Burgdorf. —*Beton u. Eisen*, 1921, pp. 70, 71.

NEW REINFORCED CONCRETE VIADUCT AND BRIDGES AT DOVER.

The viaduct and bridges which have been in course of erection since 1913 with a view to alleviating the congestion of traffic between the main portion of Dover and the part in the vicinity of the Admiralty Pier have now been completed, after many delays owing to the war.

The improvement scheme included the construction of an elevated roadway with two bridges on the western side of the Harbour Station and a spur or branch viaduct, and a third bridge carrying a street over the lines of the S.E. & C.R.

The main viaduct has a total length of about 1,000 ft. The spur running from it is about 200 ft. long, while the separate overbridge has a span of 68 ft. The main viaduct also includes two bridges, of 70 ft. and 65 ft. span respectively, one over the Drainage Works and the other over the Dover & Deal Railway. Starting from the Town Station end, the viaduct for a distance of 152 ft. rises gradually between retaining walls, till a length is reached which is carried on a series of seven arches, averaging 31 ft. in span. The Dover & Deal Railway is next crossed by a bowstring girder bridge, slightly on the skew, and with a clear opening of 65 ft. The viaduct then continues on seven arches of about 31 ft. span, on a curve, after which the spur branches out from a 40 ft. span. After two more 31 ft. and 37 ft. arches is the second bowstring girder bridge, with a clear span of 70 ft., over the Drainage Works. The viaduct ends with a series of six arches, averaging 35 ft. in span, on a falling gradient. The spur consists of a length on arches, and an end section of filling between retaining walls. The separate bridge of 68 ft. span over the S.E. & C.R., similar in type to the other two, has not yet been built.

The clear span of the bridge carrying the viaduct over the Dover and Deal Railway is 65 ft., the opening between 67 ft. measured parallel with the girders, while the bottom boom has a length of 74 ft. over all. Each bowstring girder comprises six open panels and two end panels filled in with reinforced concrete. The girders are 23 ft. 6 in. deep at the

Fig. 1. Part of Viaduct and Spur Viaduct.

Deal and Dover Railway Bridge and Part of Street Viaduct.

Fig. 2. Dover and Deal Railway Bridge.

centre, measured from the top to the underside of the bottom boom. The latter is 12 in. wide by 48 in. deep reinforced by four bars at the bottom and a similar number at the top. The top curved boom is 12 in. by 21 in. in cross section, the reinforcement increasing towards the centre to eight bars. The uprights are 12 in. by 18 in. in cross section, the central member and the members on either side being reinforced by four vertical bars in each case. The remaining four uprights are reinforced by four vertical bars. The diagonal struts are of uniform cross section, 12 in. by 18 in., and are reinforced by four longitudinal bars. The bridge has a central roadway and two footpaths carried on cantilevers. The main girders are 31 ft. apart from centre to centre, and beyond them project the cantilevers, the distance from the centre line of each girder to the inside of the parapet at the end of the corresponding cantilever being 7 ft. The main girders are braced at the top by two beams, each 24 in. wide and tapering from 15 in. down to 9 in. deep. The main transverse deck beams are 10 in. wide and project 30 in. below the 6 in. flooring. The longitudinal beams beneath the bowstring girders are of similar dimensions. The cantilevers projecting from the transverse beams run into an outside longitudinal beam below the parapets. The latter are of ornamental design and 5 ft. in height. The flooring of the footpaths is 3 in. thick. The bridge was calculated for a load of 140 lb. per sq. ft., in addition to metalling, and when tested with a distributed load of about 1,000 lb. per sq. ft. on a test area, the net maximum deflection at the middle of the floor beam worked out at $\frac{1}{7650}$ of the span, equivalent to nearly one-thirteenth of the permissible amount. Another test on the bridge consisted of rolling load tests, first with one traction engine and three loaded trailers, and then with two trains so composed side by side, both passing as closely as possible to the girders on either side of the bridge. The traction engines weighed 14 tons each and the loaded trailers 12½ tons each. The maximum loading on the bridge under the conditions stated was 96 tons, and the resulting maximum deflections worked out at $\frac{1}{11780}$ of the span for the main girders, and at $\frac{1}{21000}$ of the span for the secondary beam, compared with $\frac{1}{800}$ of the span as allowed by the specification. No permanent set was recorded in either case. During this test the railway engineers checked the two main girders for spread at the centre of the top booms, but detected no lateral movement, the two reinforced concrete cross ties resisting such a tendency effectively.

Tests were carried out on the Drainage Works Bridge with rolling loads, consisting in the first test of a 14-ton tractor and three 12½-ton loaded trailers. This bridge has a clear span of 70 ft., and all the wheels of the train, making a total load of 51½ tons, could be got on the span. The second test on the same bridge was made with two similar trains, or a total load of 103 tons. Under the most unfavourable load conditions, the maximum deflection of one of the main girders was $\frac{1}{111250}$ of the span, and the maximum deflection at the centre of the middle cross beam, considered by itself, was $\frac{1}{15700}$ of the span, compared with $\frac{1}{600}$ of the span permitted by the specification.

The elevation and plan shown in *Fig.* 5 are of the length of viaduct extending between the two bowstring girder bridges over the Drainage Works and the Dover & Deal Railway. The length illustrated in *Fig.* 4 is that extending south-east from the latter bridge and terminating in the ramp between retaining walls which rises from the street level close to the Town Station. For the greater part of its length this section is straight, but at the higher end begins to curve slightly. In this length the viaduct is carried by rows of columns supporting two main longitudinal beams and two external beams. The whole width is thus divided into three longitudinal sections, the beam centres being 15ft. apart. At the higher end the curvature is obtained by displacing the external beams slightly laterally, the two central beams being run straight on from one end of this part of the structure to the other. The beams rest on reinforced-concrete columns, those for the central beams being 18 in. by 18 in., and those for the side beams 18 in. by 12 in. in cross section. The spans in this part vary from 33 ft. 10 in. to 40 ft. The construction of the outside beams of the 40 ft. span is shown at the bottom of *Fig.* 4. For these arched beams the reinforcement consists in the centre at the top of two long bars, and two short bars. At the bottom the continuous arched bars are two in number, while two other curved bars reinforce the arch on the under side in the centre, and are deflected to the upper side at the columns. In the shorter spans there are two top bars and two bottom curved bars. The central beams for the 40 ft. span have a section of 12 in. by 26 in. below the 6 in. flooring ; in this case the depth at the springing is not so great as in the outside beams. The reinforcement at the centre is increased to nine bars below and six bars above. The central beams, at the extreme right of the plan in *Fig.* 4, running out into the abutment wall and columns, are reinforced in two systems only, as is the case with all the shorter spans. In this particular pair of beams there are six bottom bars and four bars at the top, in the centre. At the extreme left of

FIG. 3. VIEW BENEATH VIADUCT.

the plan the main central beams do not run directly into columns, but make junction with the abutment wall. On account of the unequal distribution over these beams the reinforcement is increased to eight bars at the bottom in the centre. The secondary beams are spaced about 3 ft. 4 in. apart, and are 7 in. wide, extending 14 in. below the floor. The decking in the centre is 6 in. thick, with ½-in. and $\frac{7}{16}$-in. reinforcement, while for the side paths the decking is 3 in. thick, with ¼-in. reinforcing bars at 6-in. spacing.

The section between the two bridges is mainly curved to a radius of 404 ft. 6 in., the spans shown in elevation being those measured on the longitudinal centre line.

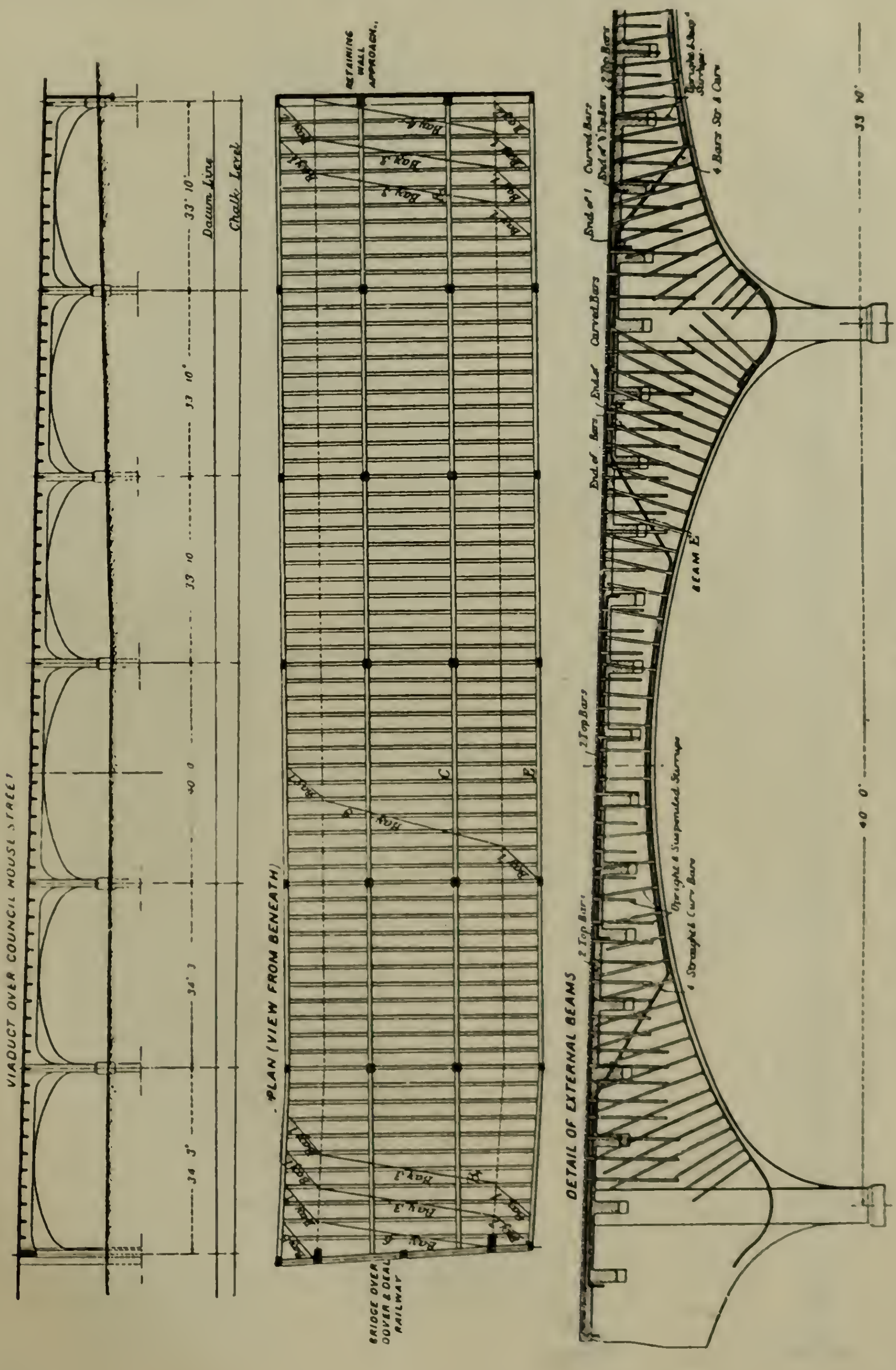


Fig. 4. Details of Viaduct between Railway Bridge and Beach Street.

The first test on one of the 40 ft. spans of the viaduct was made with two trains consisting each of a 14-ton tractor and 12½-ton loaded trailers. Only one trailer could be got on the span behind each tractor, so that the load amounted to 53 tons with the two trains, and this came mainly over the central longitudinal arch beams. The maximum deflections recorded at the middle of these beams amounted to $\frac{1}{4520}$ and $\frac{1}{5440}$ of the spans respectively. Other tests were made on the 40 ft. span at the junction of the viaduct and the spur, including a static load test of 71 tons 4¾ cwt., concentrated on an area 15 ft. wide over one of the central beams, and extending over a strip 3 ft. 4 in. wide over a cantilever on each

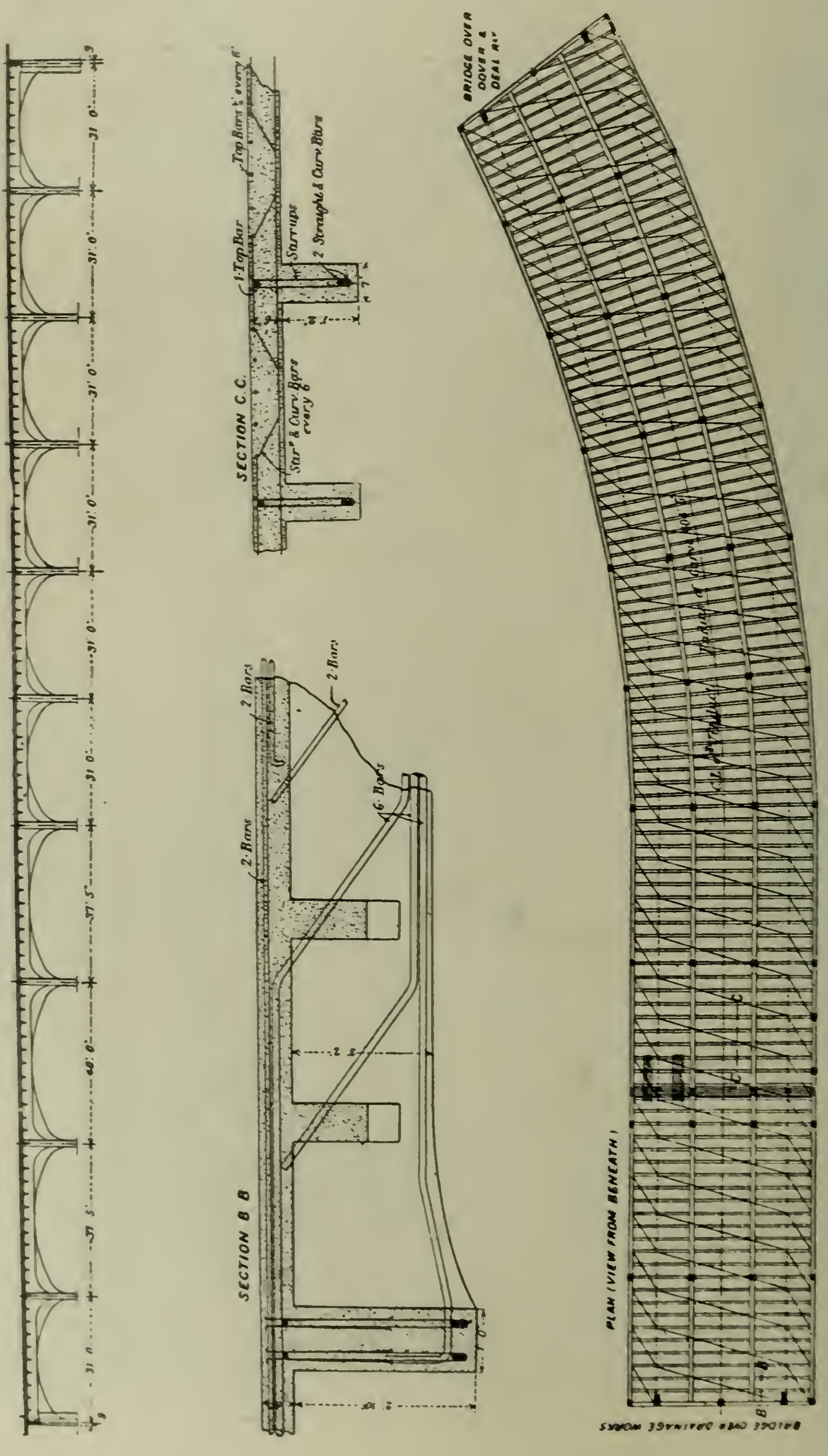


Fig. 5. Details of Viaduct between Bowstring Girder Bridges.

side. This allowed 10 tons 6 cwt. for road metalling, plus a test load of 210 lb. per sq. ft. The worst deflection at the point of the central longitudinal under the middle of the load was [illegible] of the span, all other measurements showing smaller figures. In another test at this point a static load of 50 tons on one longitudinal beam was combined with a rolling load of 26½ tons passing over the other beam, the deflection being of the same order as that last mentioned.

A test on the 33 ft. 10 in. span nearest the retaining wall approach at the Town Station was arranged with a static load of 24 tons, distributed over an area of 254 sq. ft., which extended for the length of the span from one side longitudinal

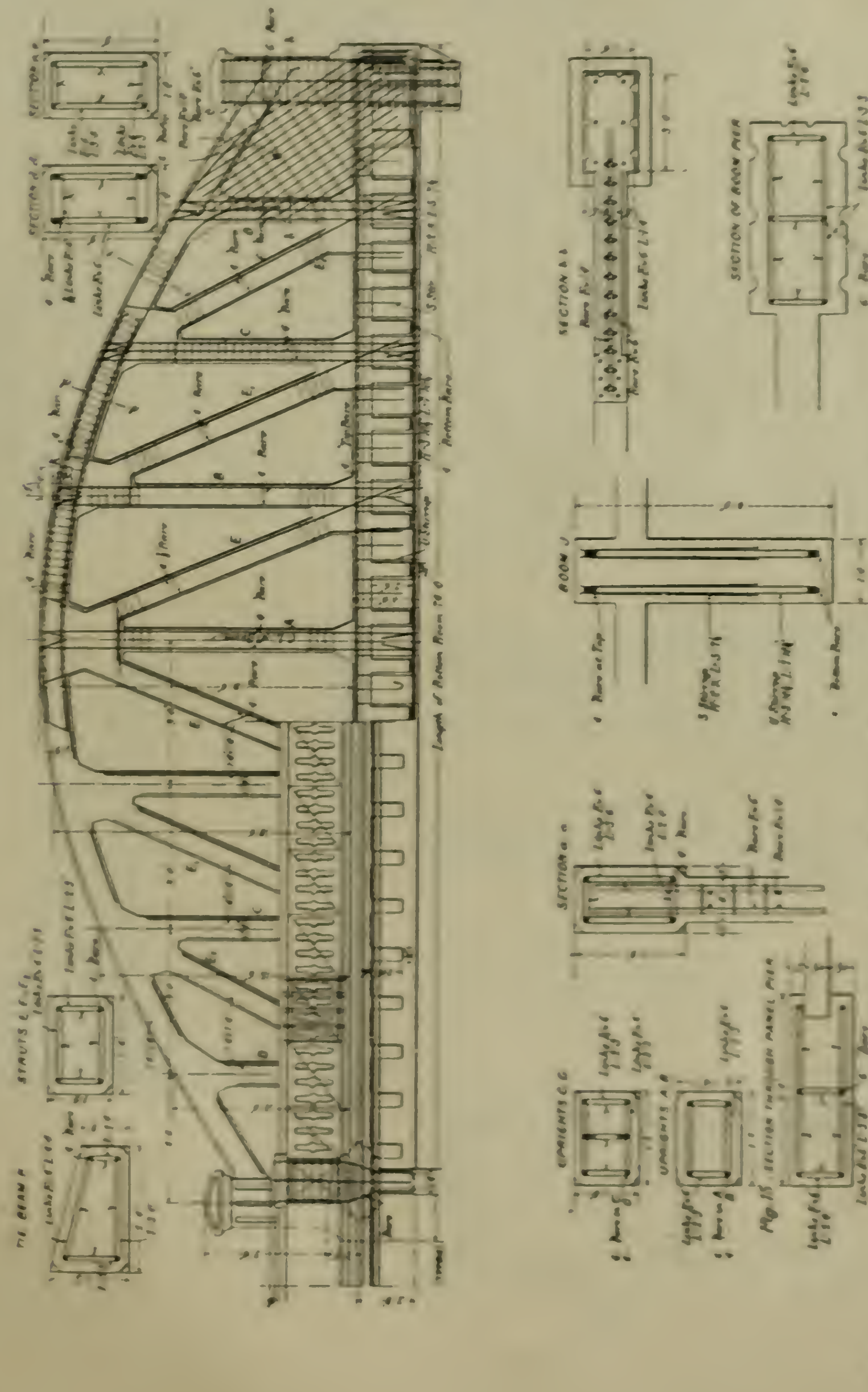


FIG. 6. DETAILS OF DOVER AND DEAL RAILWAY BRIDGE.

beam out to a distance of 7 ft. 6 in. over the decking. As close to this load as possible were placed two 14-ton tractors side by side, each with a $12\frac{1}{2}$-ton loaded trailer behind it. The effect of this arrangement was to concentrate the whole of the load on a space two-thirds of the width of the viaduct. Deflection was taken at the centre of the central longitudinal beams, and of the side longitudinal under load, and also at the centre of the middle secondary beam in the side bay. The deflection in the latter case amounted to $\frac{1}{11430}$ of the span, and the worst deflection of the longitudinals, that of the beam in the middle of the loaded two-thirds, amounted to $\frac{1}{3965}$ of the span, the allowable deflection according to the specification being $\frac{1}{600}$th of the span.

The abutment wall at the end adjoining the first span is 9 in. thick, and embodies four columns to take the main beams. These columns are 12 in. by 25 in., and 16 in. by 25 in. The side walls are 5 in. thick at the bottom, tapering to 4 in. at the top, with vertical reinforcement every 8 in. and horizontal reinforcement spaced 5 in. apart for the lower part, $5\frac{1}{2}$ in. apart for the middle portion, and 10 in. apart for the upper section of the wall. The side walls have a small toe extending 15 in. on the outside and a much larger one on the inside to take sufficient load to prevent risk of overturning. The latter flooring extends inwards to various distances, according to the height of the wall. The wall is cut up into sections, with inside counterforts tying together the wall and the floor. These are 8 in. thick, and the reinforcement for one of the tallest is shown in *Fig.* 7. At two intermediate points and one end ties extend across from wall to wall at the lowest level. These are rectangular in section and measure 12 in. by 18 in. They are reinforced by four $\frac{15}{16}$ in. bars.

The works were executed under the superintendence of Mr. W. C. Hawke, the former Borough Engineer, and Mr. W. Boulton Smith, the present Borough Engineer of Dover, by Messrs. Lambrick & Co., Public Works Contractors, Burton-on-Trent. The whole of the reinforced concrete work was on the Mouchel-Hennebique system, and Messrs. L. G. Mouchel & Partners, Ltd., of Westminster, were associated with the work as consulting engineers.

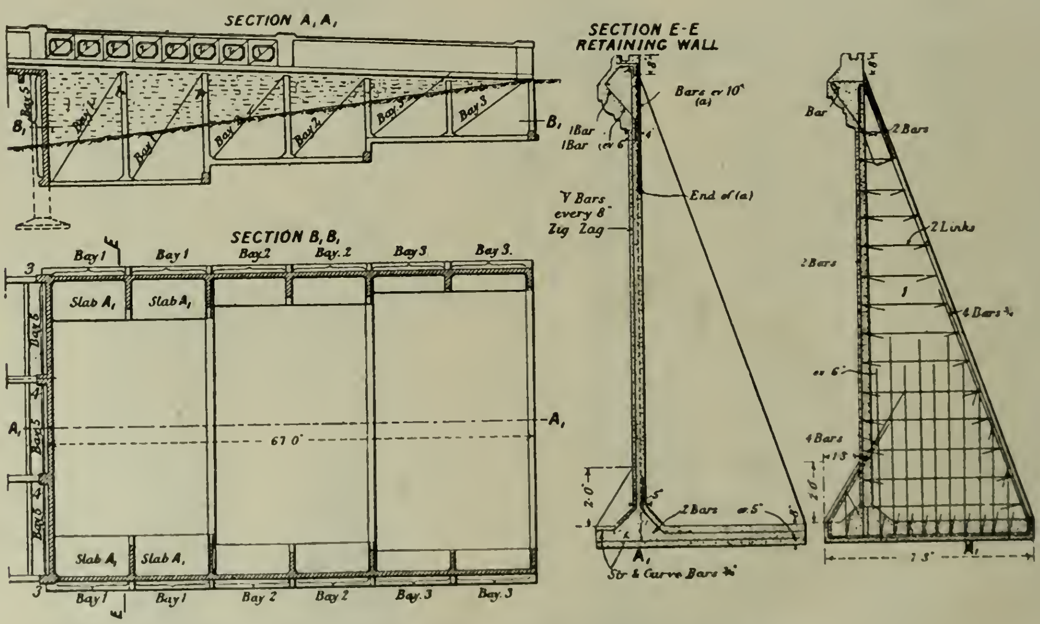


FIG. 7. DETAILS OF RETAINING WALL SECTION OF VIADUCT.

ANNUAL GENERAL MEETING AND ANNUAL REPORT.

THE annual general meeting of the Concrete Institute was held at 296 Vauxhall Bridge Road, S.W., on April 27, Mr. E. Fiander Etchells presiding.

In presenting the annual report and balance sheet, the CHAIRMAN said the report showed the Institute was making good progress. It was in an increasingly sound position, and there was every evidence that that position would be still further improved and consolidated. The annual report did not deal with the proposal to change the title of the Institute; the Council had considered the question, but the decision must lie with the members. It was probable that the Council would ask the members to agree to the title of the Institute being changed to "The Institute of Structural Engineers, Incorporating the Concrete Institute." For the past ten years the Institute had been dealing with all branches of structural engineering. The Institution of Civil Engineers dealt with practically every branch of civil engineering, but amongst the special branches of engineering, of which structural engineering was one of the principal, it was to be hoped that their Institute would do its share.

Major PETRIE (Chairman of the Finance and General Purposes Committee) moved the re-appointment of the auditors, Messrs. Monkhouse, Stoneham & Co., and this was agreed to.

Mr. W. J. H. LEVERTON moved the adoption of the report, which was agreed.

In reply to a question, the CHAIRMAN said an Institution of Structural Engineers had been formed, and if both parties were agreeable joint meetings might be arranged. It was his hope that those meetings, besides being held under one roof, would also be held under one control.

The report of the Council of the Institute for the year 1921–22 states that the total membership at the end of March, 1922, was 1,237, a net increase of 100 during the year; the number of new members enrolled constitutes a record.

The receipt of a cheque for £250 from the Concrete Utilities Bureau towards the establishment of a Medal Endowment Fund is acknowledged.

The Officers and Council for the Session 1922–23 are as follows:—

President.—Mr. E. Fiander Etchells.

Vice-Presidents.—Messrs. J. Ernest Franck, J. S. Owens, H. J. Deane, James Petrie, C. F. Marsh.

Past Presidents.—The Rt. Hon the Earl of Plymouth, Sir Henry Tanner, Professor Henry Adams, Mr. F. E. Wentworth-Sheilds, Mr. H. D. Searles-Wood.

Council.—Messrs. E. S. Andrews, H. K. G. Bamber, P. J. Black, H. F. Bladen, W. E. A. Brown, D. B. Butler, W. C. Cocking, J. S. De Vesian, H. Kempton Dyson, Oscar Faber, W. A. Green, E. L. Hall, B. L. Hurst, W. J. H. Leverton, E. R. Matthews, A. E. Meston, F. Purton, Sir Charles T. Ruthen, Messrs. A. Alban H. Scott, Archibald Scott, R. H. Harry Stanger, H. E. Steinberg, R. W. Vawdrey, G. C. Workman, and M. E. Yeatman.

WHAT IS THE USE OF THE MODULAR RATIO?

By H. KEMPTON DYSON.

[*Continued.*]

Reinforced Concrete Beams.

Coming now to the consideration of reinforced concrete beams, if we turn back to the early pioneers we find first of all that their work was done with next to no calculation ; slabs and beams were tested to destruction, and in the light of such experiments buildings and parts of buildings were constructed, the sizes being roughly proportioned from the data thus obtained.

When the pioneers of reinforced concrete construction in Germany, Belgium and France began to get well under way and to carry out extensive structures in the material, some discussion took place amongst Continental engineers as to the proper mode of calculation. M. Edmond Coignet, together with his engineer M. N. de Tedesco, it has been stated, were the first to suggest introducing the modulus of elasticity of the concrete, and of the steel, into the calculations. Then Monsieur Considère and others elaborated the theory, and at first, in the light of some experiments of his, the concrete on the tension side of a rectangular beam of reinforced concrete was taken into account. Then when it was found that in practice the concrete was cracked on the tension side the tensile resistance of that material was omitted, and the ordinary current theory was arrived at, to which the American Professors Hatt, Talbot, and Withey, and the German Professors Mörsch and Bach made notable contributions, from whose experiments a justifying co-efficient was chosen to make the formulæ somewhat fit the experiments, the said co-efficient being now termed the modular ratio, seeing that it purported to be derived from the moduli of steel and concrete, the two elements of the combination.

For many years past the author has expressed dissatisfaction with the customary mode of calculating stresses in reinforced concrete members transversely loaded, because some of the assumptions upon which the mathematical treatment is based are illogical, while others are not in agreement with fact. In a previous paper by the author on "Shear" it was pointed out how the concrete was ignored in tension because of the stated possibility of cracks extending from the convex side of a so-called "beam," and yet certain modes of calculation had been put forward as a means of determining the shearing stresses whereby horizontal shear was required to be transmitted from section to section, forgetting that it could not pass across a crack. In short, the demonstrations were inconsistent. But the trouble was deeper rooted than that. It was not merely the case that the method of determining shear stresses referred to was wrong, but the fundamental assumption about the stresses being directly proportional to the distance from the neutral axis was wrong—again because of the cracks. A reinforced concrete member subjected to transverse loading may, if uncracked initially, start by the strain being directly proportional to the distance from the neutral axis, which will be located not at the ordinary centroid of a homogeneous section, but in a position corrected for the steel having a different modulus from the concrete. But though at first a reinforced concrete member may act truly as a beam, the neutral axis of which, allowing for the reinforcement, starts at approximately 54 per cent. of the effective depth from the compressed edge, yet as, in order to obtain economy, we naturally reckon upon putting a fairly high tensile stress into the steel under working loads, the result will be that with quite a moderate stress in the steel the concrete will be cracked on the convex side. These cracks are minute as a rule, so that when air penetrates to the steel no corrosion will take place by reason of the presence of the alkaline lime compounds of the cement. These cracks are reduced in size and in number by making members fairly deep. After all, the cracks are due in a sense to curvature in bending, and as the deflection varies directly as the cube of the depth, it is easy to see that a small increase in depth will make a great difference in the deflection and the radius of curvature. In properly designed reinforced concrete, cracks are very small and may not be noticeable to the naked eye, nor to the casual observer, so that such structural members may appear to be homogeneous units. The fact that cracks do occur, however, renders the structures really compound ones, in which the concrete and steel act as separate elements, though connected together. Thus, in reality, such a member is not a beam—it is more in the nature of an arch or elemental frame.

Figs. 7 and 8 illustrate the sort of simple frames that result from concentrated or point loads on so-called beams of reinforced concrete, the dotted lines representing the compression struts produced within the concrete. The drawings also illustrate the probable form of the minute cracks that would be formed in the underside about the middle of a beam by the stretching of the steel.

Figs. 9 and 10 are similar diagrams, but in relation to two concentrated loads upon a single beam. When the load is evenly distributed, the compression-strut action results in

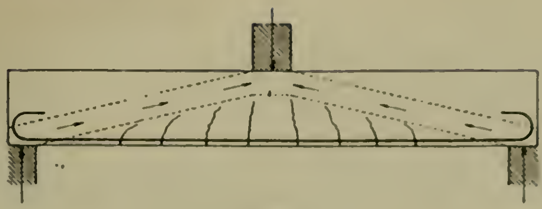


Fig. 7.

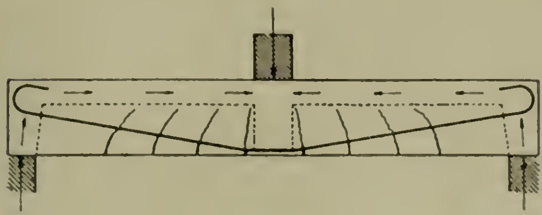


Fig. 8.

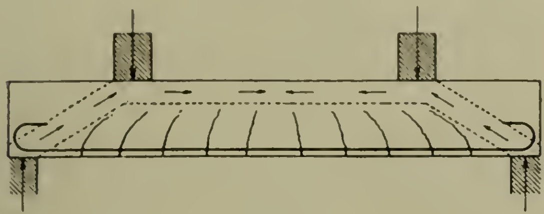


Fig. 9.

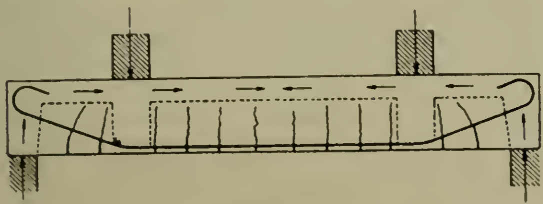


Fig. 10.

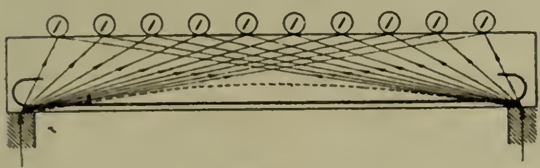


Fig. 11.

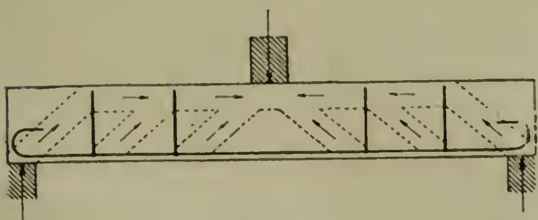


Fig. 12.

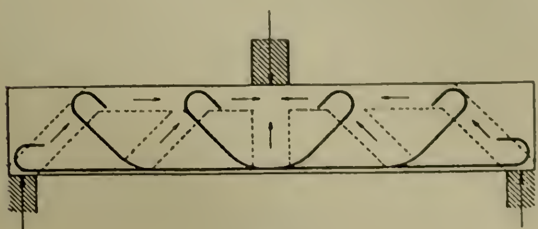


Fig. 13.

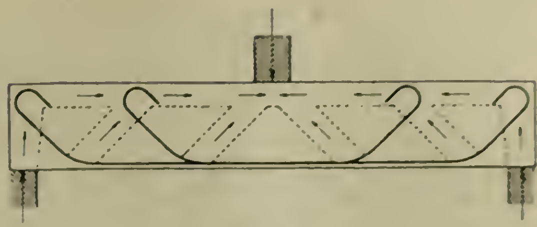


Fig. 14.

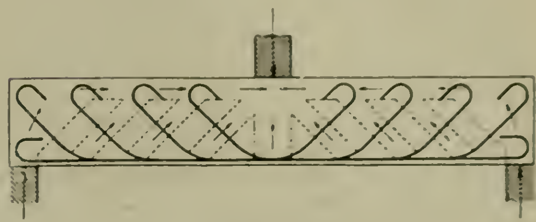


Fig. 15.

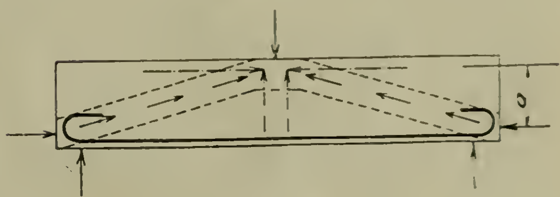


Fig. 16.

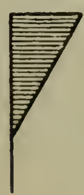


Fig. 17.

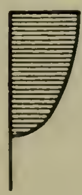


Fig. 18.

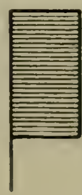


Fig. 19.

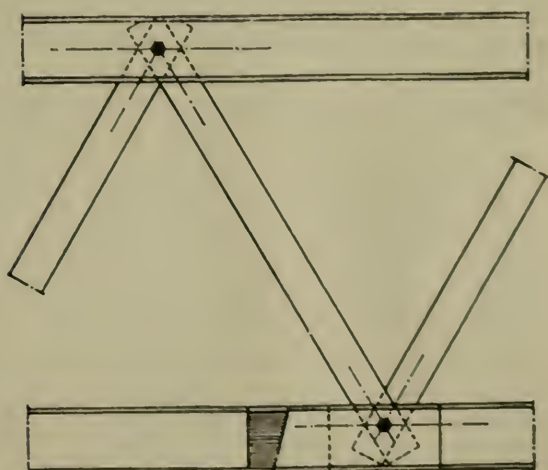


Fig. 20.

producing a curved formation analogous to a jack arch with a tie-rod for resisting the thrust in the arch (see *Fig.* 11).

When web members are introduced, the construction takes the form of a trussed frame, as indicated in *Figs.* 12, 13 and 14; the first being similar to an N-girder, and the second and third to a Warren girder. By super-imposition of *Figs.* 13 and 14, we get the combination (*Fig.* 15) which is very often employed in practice. There may also exist at the same time frame or arch action similar to that indicated in *Figs.* 7 to 11. The combination of vertical with inclined members is frequently adopted still further to complicate the frame and truss action, while the uncracked portions often act partly as homogeneous beams. Thus an attempt to make an accurate detailed analysis of the stresses at stages preliminary to rupture is impracticable. There are, however, certain fundamental relations in beam action that enable the breaking strength to be calculated fairly closely.

From the foregoing consideration the conclusion is drawn that we are not very sure as to how a so-called " beam " of reinforced concrete is really going to act: it may be a sort of arch or a simple frame, or a truss. When, indeed, it comes to building a slab to rest on its edges there may be developed a sort of flat dome or a cone or a pyramid within the thickness.

As to how much of the concrete is cracked throughout the length of the member cannot be determined with any accuracy. When the concrete cracks, the steel reinforcement will slip through. Series of elaborate tests carried out in recent years have shown a gradual sliding of the bars in the concrete, as the loads have increased, until most of the pull is taken by the hooks or other anchorages at the ends. We have noted that for the first time of loading the action is altogether different from what it is when cracking has occurred. Towards the ends, therefore, of a " beam " there may be uncracked sections in which the distribution of stress would be very different from that in a frame. We see, therefore, that we cannot know at all precisely the actual distribution of the deformation or strain throughout the member; consequently we have no means of determining except in the roughest manner the amount of work done. Even to make a rough approximation, it would be necessary to look closely into the detail of every design. It seems, therefore, impractical to attempt to get a solution by the theorem of least work, such a favourite resort when we are in difficulty and cannot see a ready solution by other means. Seeing that no accurate solution can be obtained on those well-known lines, though fully aware of the deficiencies of the ordinary methods, the author has demonstrated and used in practice the ordinary customary methods of calculation, as given in text-books, reports, regulations and the like. It is only within the last few years that he has been able to arrive at a simple mode of calculation which is considered to be sufficiently accurate for all practical purposes, and to be free from the mathematical inconsistencies of the current theory.

Reverting to the illustration of the cantilever and beam referred to in respect to *Figs.* 4 and 5, the same simple mechanics apply to the case of the reinforced concrete arch or frame. The resistance moment is equal to the bending moment, and the total compression must equal the total tension. If the concrete is cracked and therefore unable to resist tension, the tension must act at the centre of the steel reinforcement. The centre of pressure is not so obvious nor so easily obtained. The problem is to determine its position in order to get the arm of the resistance couple.

The same fundamental relations exist in the frame or arch. *Fig.* 16 shows this. The inclined pressure of the strut is resisted by the horizontal pull in the steel and the vertical reaction of the support. Now, we can replace any force by two or more acting at the same point. At the centre we replace the inclined force by horizontal and vertical forces called the components of the original force, as indicated by the dotted arrows. The horizontal components are the compression, the vertical components are the shear. If, instead of a frame we were dealing with an arch without a tie-rod, the abutment would have to supply the horizontal force equivalent to the tension in the tie-rod as indicated by the arrows at the ends. The tension and compression form the resistance couple, the arm of which is a, as indicated in the diagram.

The distribution of the stress in a homogeneous beam has already been described, and it has been pointed out how it may start by being triangular, as indicated in *Fig.* 17, but will change subsequently to something in the form of a semi-parabola, and then a quarter ellipse, like *Fig.* 18, and may even approach a rectangle as in *Fig.* 19. What, now, is the probable distribution of stresses in the compressed area of a reinforced concrete member subjected to bending? By analogy with the arch or the frame the stress must be much more uniform from one fibre to another than if we look upon it as a beam of elastic material. In a truss or frame the neutral axis has nothing to do with the distribution of stress. For example, let us consider just a panel of a Warren truss, in which the joints are hinged so that the pressure passes through the hinge. If in the compression boom of such a truss the hinge be placed below the centroid of the section so as to produce an eccentric thrust the stress will be actually greater on the lower edge of the compression boom than it is on the top, as indicated in *Fig.* 20. In reinforced concrete it has been argued that because cracks result from bending, and run upwards into the beam, just above the point to which they extend the concrete will start to be in compression and owing to the curvature the outer fibres will be compressed more than those near the middle. This may appear a good argument at first sight, and conflicts with what has been indicated as to what could happen by frame action. The inclined compression struts and diagonal tension members of a reinforced concrete truss (which is really what a cracked reinforced concrete member becomes), the horizontal components of which create the compression in the boom, certainly appear to communicate their inclined forces to the under-side of the compression boom, so that the first argument would still appear to be somewhat relevant.

Let us see if we have any experimental data to settle these differences. The majority of bending tests on reinforced concrete members are on sections reinforced with a small percentage of steel, namely, 1 per cent. or less. With such a limit the reinforcement is the weaker element, and the compression could be safely carried on a small top boom of concrete. Any number of experiments show that whenever small percentages of steel are used with a fair quality concrete the so-called neutral axis travels upwards, indicating that a smaller and smaller area comes into play to resist the compression. Naturally if the reinforcement is weak it will be stressed beyond the yield-point, and will begin to deform plastically, with the result that the beam will go on deflecting, the radius of the curvature will increase, and cracks open wider, making the area left to take compression less. When rupture finally occurs in such cases we do not, as a rule, find the steel snapped apart, nor, indeed, on examination of the steel out of broken beams do we notice any stricture or waist. The bars, indeed, when tested, appear to be as good as before. We find, therefore, on ultimate rupture, that it is the concrete which appears to be crushed on the concave side whereas the steel was really the primary cause of failure.

By the ordinary theory if the steel becomes overstrained its apparent modulus will be lowered. In a beam weak in tension this means that the modular ratio will tend to be reduced. A lower modular ratio means that the neutral axis will rise. So far the ordinary theory agrees, but while the steel is stretching the area in compression is being reduced, and the concrete must be having its modulus reduced also. The modular ratio is therefore an unknown quantity. But so far as small percentages are concerned there is no need to import such a factor into the equations for determining the ultimate strength. We have a sufficient criterion in the fact that the total compression must always equal the total tension. It looks as though Nature enabled an adjustment to take place so as to assist the over-strained steel as much as possible, throwing on the stronger element of concrete a bigger share until finally it, as the less ductile material, crushes. The steel is really the primary cause of failure owing to its weakness, but when ultimate failure does occur, both the concrete and steel are taking the maximum they are capable of developing.

If we know the maximum stresses to be attained in the steel and the concrete and adopt some distribution for the compressive stresses in the fibres we can express all the fundamental relations without recourse to the modular ratio. Thus if we say the distribution is triangular then for a rectangular section $C = \frac{1}{2}bcn = \frac{1}{2}bcdn_1$, while $T = tA = tA_1bd$. But $C = T$, therefore $n_1 = 2A_1\frac{t}{c}$, where t and c are maximum stresses for the materials.

Now, on the other hand, what happens when the steel is the stronger element? Few tests have been carried out with high percentages of reinforcement, but those that have afford some very striking results. These tests appear to have been overlooked, yet they are of extreme importance. Firstly I would refer to Professor Talbot's experiments of 1904 at Illinois University. In those tests special precautions were taken against failure by shearing or secondary stresses, and the sizes adopted were such as would approximate to those under ordinary working conditions. The longitudinal deformations during loading were carefully and accurately measured with a view to determining the position of the neutral axis. With this object two extensometers were placed on one side of the beam. The concrete was mixed moderately wet in the proportion of 1 cement, 3 sand and 6 coarse material. The loads were applied at two points, one-third the length of the span from either support. Reference will be made to two beams Nos. 27 and 28. Their size was 12 in. by 13½ in., the depth to the centre of the reinforcement being 12 in. The span of the beam was in each case 14 ft. The length of the central portion of the span where the metal had its full section, no bars being bent up, was 60 in. The age was 63 and 61 days respectively. The reinforcement of beam No. 27 consisted of four ¾-in. plain square bars giving a percentage of metal of 1·56. In beam No. 28 six ¾-in. Johnson corrugated bars were used giving a percentage of reinforcement of 1·52. The elastic limit of the square bars was stated to be 33,000 to 35,000 lb. per square inch whereas for the Johnson bars the elastic limit was 55,000 to 60,000 lb. per square inch. The ultimate resistance of these two kinds of steel was not stated, but for the mild steel was probably about 50,000 lb./in.^{2}, judging by what Professor Talbot gave for similar steel in the following year's tests. The ultimate strength of the Johnson bars was probably quite 80,000 lb./in.^{2}

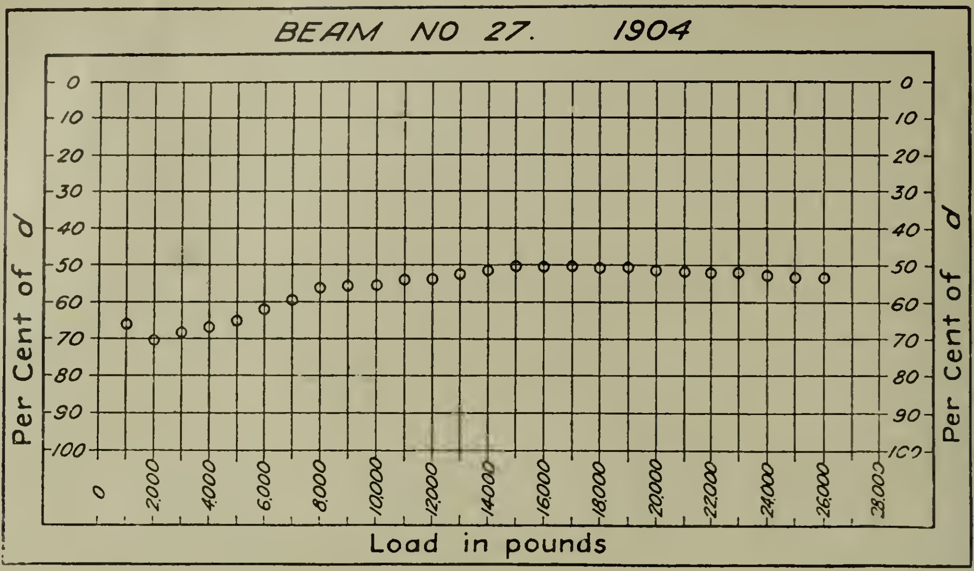


FIG. 21.

Fig. 21 shows the movement of the neutral axis in beam No. 27 with mild steel reinforcement, and *Fig.* 22 the movement of the neutral axis in the case of beam No. 28 having the stronger steel. Beam No. 27 carried a maximum load of 26,900 lb. and beam No. 28 a maximum load of 34,300 lb. We note that in the first case the neutral axis travels upwards at first and then remains fairly even to the end, though slightly dropping, whereas in the second case after travelling slightly upwards it distinctly travels downwards towards the end of the test. What explanation is there for these tests on the ordinary theory ? Both steels must have had about the same modulus. The concrete was probably very similar, and there were practically equal percentages of steel. Yet the positions of the neutral axis differ materially. If in the former case the mild steel is stressed beyond the yield point nearing the breaking load, we should expect, for reasons explained above, to find the neutral axis going up. Instead of that it descends slightly. That looks very much as though the concrete were the weaker element. In the latter test the steel was still stronger than in the former, and the recorded values show a gradual lowering of the neutral axis. How far the neutral axis dropped at actual rupture could not be observed, of course. The only way the ordinary theory could account for this is on the basis that through overstrain the modulus of the concrete was lowered and the modular ratio increased. But we are usually advised to adopt a set value throughout. Seeing that both steels had the same modulus, and that the concrete was the same in both cases, we would conclude that the ordinary theory would make the modular ratio the same—yet the two results are different, and the only way to attempt to reconcile the ordinary theory with the facts is to adopt a different ratio for each

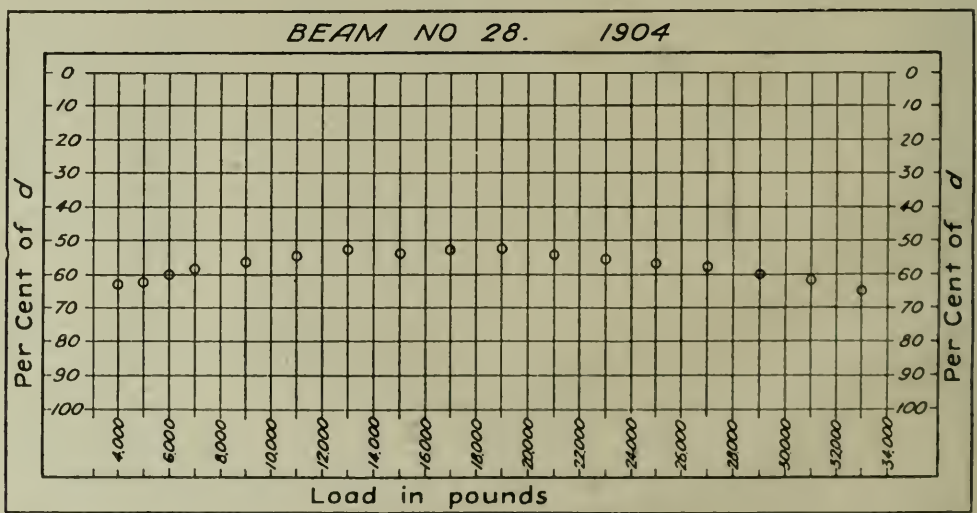


FIG. 22.

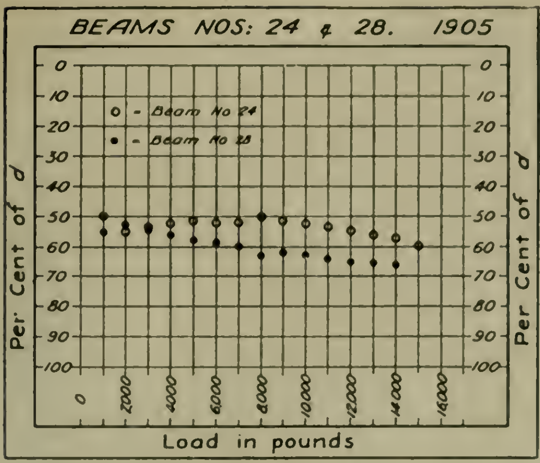


FIG. 23.

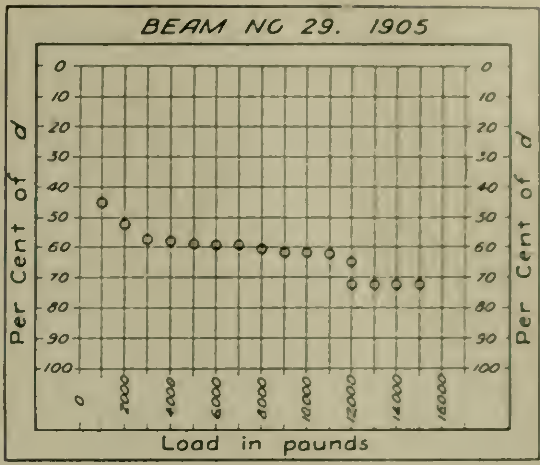


FIG. 24.

case. These two tests bring out that the stronger steel can develop a greater amount of resistance by bringing more of the concrete in to resist compression. The concrete will begin to squeeze, and more and more will come into play; as the outer fibres give way a more equal stress is put on the inner fibres, just as we have seen for homogeneous beams. If, once more, we want to calculate the ultimate resistance moment we need no modular ratio—we can proceed as in the case of small percentages, but there is a limit in that we cannot bring more concrete into play than the total depth of the beam, and if the steel is strong enough to do that we can no longer use the foregoing equation for the neutral axis ratio, nor do we want to do so because n_1 becomes simply 1. We only need to know the limiting percentage of steel for any particular strengths of steel and concrete. This will be given by putting $n_1 = 1$ in the foregoing formula, and inserting values for t and c; thus for triangular stress distribution

$$n_1 = 1 = 2A_1\frac{t}{c} \text{ and } A_1 = \frac{c}{2t}.$$

In Professor Talbot's further experiments in 1905 a similarly proportioned concrete was used. Four beams are signalled out for comment here, namely, Nos. 24, 28, 29 and 46. The ages respectively were 63, 60, 62 and 61 days. The beams measured 8 ins. in width, 11 in. in depth and 13 ft. long, with a test span of 12 ft. The steel reinforcement was placed 10 in. below the top surface, and consisted of mild steel of two qualities, the bars being mixed indiscriminately. One quality had a yield point of 33,200 lb./in.², and ultimate strength of 51,900 lb./in.², while the other had a yield point of 43,600 lb./in.², and ultimate strength of 62,350 lb./in.². The loads were progressively applied and released in the first two cases, but in the third a load of 12,000 lb. was repeated 15 times. In the fourth case the loading was continuous.

The first three beams were reinforced each with four ¾-in. plain round mild steel rods, thus giving a percentage of reinforcement of 2·21, while beam No. 46 contained five ¾-in. plain round mild steel rods, thus giving a percentage of 2·76.

Figs. 23 to 25 give the records showing the position of the neutral axis at the various loads.

The maximum loads carried were: Beam No. 24, 15,600 lb.; beam No. 28, 14,300 lb.; beam No. 29, 15,900 lb.; and beam No. 46, 15,300 lb. In all cases the neutral axis travelled downwards, and in beams 29 and 46 reached so near the bottom as 72 and 80 per cent. of the depth. The final position at rupture could not be observed. In these tests we have mild steel in sufficient quantity never to be stressed to its ultimate resistance.

Both in the 1904 and 1905 tests there is a paucity of information about the real strength of the concrete. In 1904 the concrete cubes were stated to be wetted for three days, whereas the curing of the concrete in the 1905 tests was admittedly insufficient. Six cubes in 1904 gave an average crushing strength of 2,030 lb. per square inch. Analysis of the tests would suggest that the strength of the concrete actually in the beams was very low, somewhere in the neighbourhood of 1,300 lb. per square inch. In 1905 the cubes that were crushed did not relate to the particular beams that are here singled out; the cubes that were tested, however, relating to other beams of the series, gave such figures as 777, 816, 1,105, 1,310, 1,355, and 1,590 lb. per square inch. Not only were no proper precautions taken to prevent the beams and cubes drying out too quickly, but the beams were handled and stacked at an early stage.

The test of beam No. 29 is interesting because of the fact that a load of 12,000 lb. was repeated 15 times. The effect of this repeated loading is clearly shown on the diagram by the upper and lower readings for that loading. This test brings out the point that the successive plastic deformations produced by re-loading in this way merely made the member settle down to its work, putting it properly into the condition of a simple frame or truss, in which the distribution of stress in the compression boom would be more uniform than it was in the early stages of loading. That in itself puts a reinforced concrete " beam " in a different category from a homogeneous beam made of material whose tensile is different from its compressive strength, of which it has been explained that the plastic deformation due to re-loading might result in eventual rupture in tension, whereas in the reinforced concrete beam the repeated loading has no deleterious effect, merely serving to make the stress more uniform even than the assumed elliptical stress distribution, tending to give a rectangular stress distribution to which frame or truss action directly points.

In the first report sheets Professor Talbot regarded beam No. 29 as failing by diagonal tension, but he expresses his final opinion that the failure was through compression. Seeing that beam No. 24 carried 15,600 lb., which is near that carried by beam No. 29, it is probable that the failure in that case also was by compression, and this inference receives confirmation from the fact that he reports the failure of beam No. 46 as caused by compression, although it carried a still lower load, namely, 15,200 lb. Beam No. 28 does not fall into line in this respect. The concrete must have been poorer than in the case of the other beams because the arrangement of reinforcement was precisely similar to beams Nos. 24 and 29. It is possible that with such poor concrete the beam failed by shear, and consequently the neutral axis was not observed to drop down so low as in the other examples.

If cracks had been developed near the middle of the beams Professor Talbot's tests would indicate they would be closed up, as more and more concrete was thrown into play; so that, indeed, the whole section could, if the design were such as to warrant it, come into play. This rather startling proposition may be made clearer by giving a diagram to show what kind of construction could enable the whole section to be stressed. *Fig.* 26 shows quite a practical scheme for an ordinary reinforced concrete beam in which the stress will obviously be something in the nature of that indicated by hatching, because the thrust in the compression boom is applied about the middle.

It was explained before that the very simple mechanics of *Figs.* 4 and 5 apply equally to a beam, arch, frame and truss, so we can ascertain all we want if we know the arm depth. In a reinforced concrete member the maximum pull will come through the steel bars, and therefore we know the centre of tension. Now, as regards the compression. If we choose any particular distribution of stress across the section we can easily compute the centre of gravity, i.e., the centre of pressure in terms of the depth of the member subjected to compression. If we have regard to ultimate loading we should be justified in adopting a stress figure like the quarter ellipse, for the case of ordinary homogeneous beams. It has already been mentioned, however, that under re-loading this might not be always true of homogeneous beams, though correct for the first time of loading, and possibly for a few successive loads. In a reinforced concrete member we have seen that the stresses may vary as a trapezium shaped figure or rectangle. The ordinary theory would ask for a triangle. The author favours an ellipse because that is probably a close enough approximation to the true distribution, yet a safer assumption to make than to assume a trapezium or a rectangle. It should be borne in mind, however, that under special conditions such a stress figure would be warrantable, and might be adopted with proper safety. The elliptical stress distribution is favoured because as a simple figure it approaches a rectangle or trapezium on the one hand as seems most appropriate to truss action, and on the other hand falls into line with the probable stress figure for homogeneous beams tested to destruction without repeated loading, and so will serve to make the student familiar with the properties of an elliptical figure for analysing tests

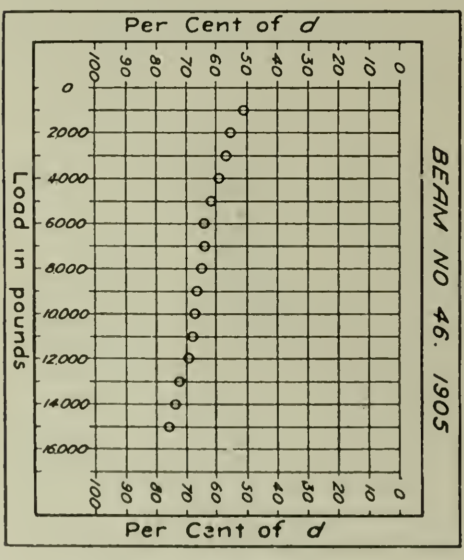


Fig. 25.

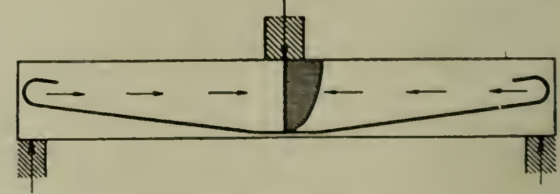


Fig. 26.

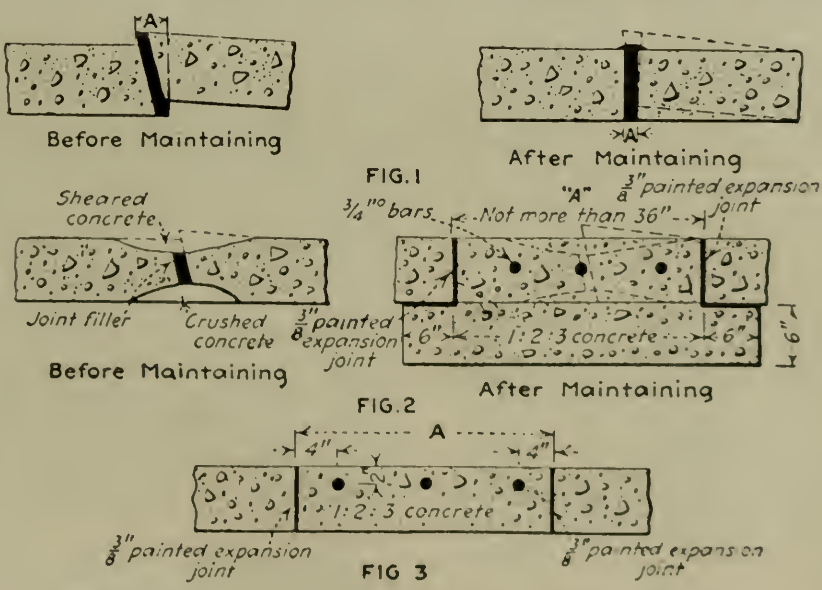
to destruction of beams of homogeneous material. At the same time it is a safe and simple assumption to make for the practical design of reinforced structures. For those, however, who would care to assume a triangular stress distribution or a parabolic stress distribution, similar properties are here set out.

If a large proportion of steel be inserted in a reinforced concrete member, we may expect more and more of the concrete to come into play to resist compression, but there must come a point where the whole section will be acting. The author feels inclined at present to limit this to the maximum effective depth, and not to take into account any concrete covering to the steel, although *Fig.* 26 would suggest that in special circumstances such would be warranted as affording greater total compression. If we adopt this procedure in practical calculation the depth of the compression boom cannot become greater than the effective depth. Up to a certain percentage of steel rupture will take place when both concrete and steel are stressed to their limits, the requisite amount of concrete being brought into play so that the total compression equals the total tension—our old fundamental mechanical principle. When, however, the whole depth of concrete is brought into play down to the steel, no more can be got out of the concrete, the arm is at its shortest and the tension at its greatest. This condition will give the maximum resistance moment in compression. If the steel is in greater proportion than merely what is necessary to balance this compression the stress on the steel will be lower than the ultimate strength. Such considerations indicate that there is a maximum amount of steel that we can usefully insert in a beam. It is desirable to emphasise this point, because the other customary theory would indicate that there was always a certain amount of advantage as regards strength to be derived from putting in a greater amount of steel.

(*To be continued.*)

REPLACING CONCRETE SLABS AT JOINTS.

Imperfect, heaved, sheared or crushed slabs at joints in concrete pavement are successfully repaired in Pennsylvania by the methods indicated by the three accompanying sketches. (1) Heaving or riding of the slab due to improper placing of the bituminous joint filler is repaired, when *A* does not exceed 2 in., by cutting out the joint with a cold chisel and refilling the opening with joint filler and coarse sand or ⅜-in. stone. (2) Concrete crushed or sheared because of the use of short or narrow



METHODS OF REPLACING CONCRETE PAVEMENT

bituminous strips of joint filler is repaired by cutting out the damaged part not exceeding 3 ft., constructing a sub-base slab, and refilling the portion cut out with concrete reinforced. (3) When the crushed or sheared section involves the replacement of more than 18 in. of each adjacent slab, or wherever the pavement slab is cracked within 5 or 6 ft. of a high, heaved, or imperfect joint, the section between cracks is removed, the slabs chiselled carefully, and the section entirely replaced with new concrete. The standard slab is used in the replacement and is reinforced with round rods spaced on 12-in. centres.—*Engineering News Record.*

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

In response to a very general request we have re-started our Questions and Answers page. Readers are cordially invited to send in any questions. These questions will be replied to by an expert, and, as far as possible, they will be answered at once direct and subsequently published in this column for the information of our readers, where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—ED.

CYLINDRICAL CONCRETE TANKS.

QUESTION.—In your February issue, under "Questions and Answers" (page 139), I notice that in reply to a question concerning the reinforcement of concrete cylindrical tanks the statement is made that if the working stresses in tension for steel (*a*) and concrete (*b*) are given "(*c*) There is an infinite number of solutions which satisfy (*a*) and (*b*)," etc. This statement is not quite correct, as for definite working stresses and a value of n there is only one solution as in reinforced concrete beams.

The proof and the formula are as follows :—

T = total tension on the section considered.

f_s = working unit stress in tension in the steel, when the tension in the concrete is neglected.

f_t = working unit stress in tension in the concrete.

n = ratio of moduli of steel to concrete,

then the area of steel $= a_s = \frac{T}{f_s}$

and this is equivalent to an area of concrete of

$$na_s = n\frac{T}{f_s}$$

and the tension carried by the concrete will be

$$T - nf_t\frac{T}{f_s}$$

which divided by f_t will give the area of the concrete. Consequently the ratio of

$$\frac{\text{Area of steel}}{\text{Area of concrete}} = \frac{\frac{T}{f_s}}{\left(T - \frac{nf_t T}{f_s}\right) \div f_t} = r$$

cancelling out T and multiplying top and bottom by f_s

$$r = \frac{f_t}{f_s - nf_t}$$

hence to get the area of steel for design

$$a_s = \frac{T}{f_s}$$

and the area of concrete $= \frac{a_s}{r}$

which is $\left(\frac{f_s}{f_t} - n\right)$ times the area of the steel.

The unit stress on the steel when acting in combination with the concrete will be $= nf_t$.

Strictly speaking $(n - 1)$ should be used instead of n in the equations to allow for the concrete displaced by the steel, but this makes no appreciable difference in the result.

I have used this method for several years for the design of tanks and pressure pipes, with values of $f_s = 11{,}000$ lb./sq. in., $f_t = 70$ lb./sq. inch, $n = 15$ for 1 : 2 : 4 concrete, and f_t and $n = 100$ and 12 for 1 : 1½ : 3 concrete.

These values give the concrete area as 142 times and 98 times the steel area respectively, or 143 and 99 times if $(n - 1)$ is used instead of n.—H. M. G.

ANSWER.—I agree generally with "H. M. G's" analysis and method of calculation, but he has misunderstood my remark. I say there is an infinite number of solutions which will not give excessive tensile stresses in the concrete, and will not give excessive stresses in steel if the concrete cracks. Saying that the tensile stress in steel shall not be excessive is, however, quite a different thing from fixing it at a definite stress—as "H. M. G." does ; and, of course, as soon as he does this there is only one solution, as he shows.

As I pointed out, the choice of arrangement out of the infinite number of possible ones, is a question of economy chiefly, and "H. M. G." gives no reason for selecting the particular one which corresponds to a steel stress of 11,000 lb./in.², though it does not differ much from the solution I suggested, and it was the *principle* involved, that the concrete stress as well as the steel stress is important for water-tightness, that I wanted to bring out.—O.F.

REINFORCED CONCRETE FLOORS.

QUESTION.—A certain type of reinforced concrete problem is giving me trouble, and I venture to hope that you will assist me in the matter.

Example.—An R.C. floor is 8 in. thick, and has the reinforcement 2 in. from the lower edge. Span of floor = 12 ft.; load per square foot = 200 lb.; fc = 600 lb. per sq. in.

Required.—Area of reinforcement, stress in steel.

Now it should surely be possible to obtain "n" by equating "R" to "M" thus:—

$$\tfrac{1}{2}.fc.b.n.\left(d-\frac{n}{3}\right)=\frac{wl^2}{8}$$

Yet this does not seem to give correct value of "n," however one brackets the equation.

I should therefore be greatly obliged if you would show me how to solve such problems.

I should very much like to get hold of a set of reinforced concrete problems, with answers, but cannot. Should you know of such a set (other than in a text-book) I should be glad to have particulars as to price, etc.—W. J. L.

ANSWER.—The reason our correspondent cannot obtain n from the equation he gives is because he assumes that fc, the concrete stress, will be 600 lb./in.² for an 8 in. slab 12 ft. span loaded with 200 lb. to the ft. Clearly this is a matter of fact, requiring calculation, and not one for assumptions.

The correct solution is as follows:—

$$\text{Area of steel} = \frac{M}{\cdot 88d \times f_s}$$

where M is the moment, and f_s the steel stress.

Taking M as $\frac{wl^2}{8}$ (following our correspondent, as he says nothing about continuity), we have

$$M = 200 \times 12' \times 12' \times \frac{12}{8}$$

$$= 43{,}200 \text{ in. lb.}$$

Taking steel stress at 16,000 lb./in.²

$$A_s = \frac{43{,}200}{\cdot 88 \times 6'' \times 16{,}000} = \cdot 51 \text{ sq. in.}$$

The percentage of steel is

$$\frac{\cdot 51 \times 100}{12 \times 6} = \cdot 71 \text{ per cent.,}$$

which, being more than ·675 per cent., means that the concrete stress will be slightly over 600 lb./in.²

To obviate this, the slab may be slightly increased in thickness, or a little more steel may be used.

In regard to our correspondent's last paragraph, we know of nothing giving exactly what he asks for without being a text-book. Perhaps "Reinforced Concrete Simply Explained," by Dr. Oscar Faber, O.B.E., D.Sc., Oxford Technical Publications, 5s. net, might help him.

REGULATIONS FOR REINFORCED CONCRETE DESIGN.

QUESTION.—I should be glad if you would please give me some information in regard to the following points:

(*a*) What is the present position as regards co-ordination in the matter of design and construction of reinforced concrete between the London County Council, The Concrete Institute, the R.I.B.A. Joint Committee, and other bodies?

(*b*) If co-ordination has not yet resulted what are the usually adopted Regulations for design and construction in various parts of the country for industrial buildings, and where can copies be obtained?—H. F. C.

ANSWER.—The professional bodies referred to were consulted by the L.C.C. in drawing up the L.C.C. regulations. These are the most generally used at present, though they are shortly to be revised, and are published by Messrs. P. S. King & Son, Ltd., of 2 Great Smith Street, London, S.W.1

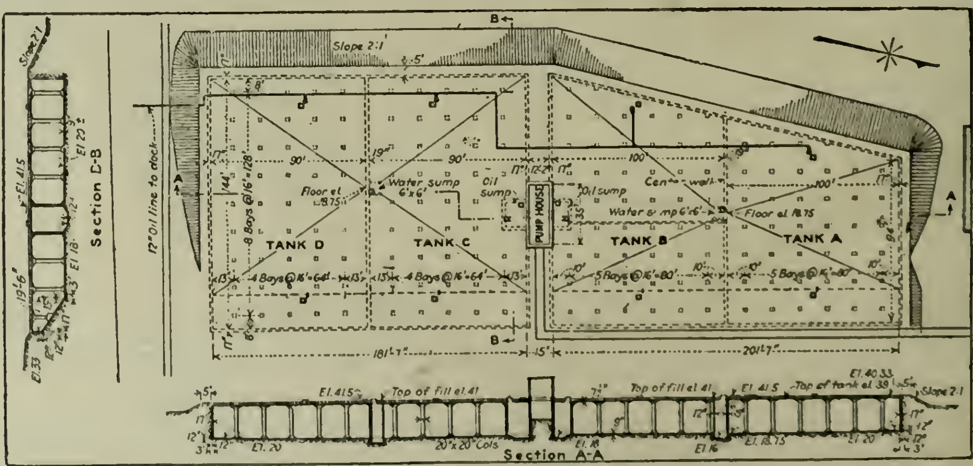
MEMORANDUM.

Concrete Ships.—It is reported that a well-known firm of London shipbrokers has purchased the concrete fleet of about thirty lighters and ten steam tugs which were constructed by the Ministry of Shipping at the end of the war for use at Richborough. The lighters have a carrying capacity of about 1,200 tons of coal each, and it is stated they are to be used on a regular coal-carrying service from the northern ports to the Thames.

A LARGE CONCRETE OIL RESERVOIR.

What is claimed to be one of the largest reinforced-concrete underground fuel-oil reservoirs has been built at Three Rivers, Quebec, for the St. Maurice Lumber Co. The structure is approximately rectangular in plan with girderless roof slabs supported on columns resting on a similarly designed floor slab and with sides reinforced to resist earth pressure from without and oil within. A special feature in construction was the proportioning of the concrete by weight in a semi-automatic device in order to ensure a uniformly strong concrete. The reservoir has a capacity of about 160,000 barrels, and is for the storage of fuel for use in the operation of the Company's new paper mill. The main plan consists of two sets of twin tanks and a centrally located pump house. One oil sump and one water sump are provided for each set of tanks. These sumps are supplied with the necessary piping and valves to permit both oil and residual water to be pumped from each tank independently.

The structure is comparatively shallow and consequently has a large superficial area. The floor along the east wall is built on a slope of 1 on $1\frac{1}{2}$, and while tanks *C* and *D* are rectangular in plan, tanks *A* and *B* are trapezoidal. The roof of the tanks is of the two-way drop panel flat-slab type and it is supported on square columns, the span being generally 16 ft. The roof is designed for a total load of 400 lb. per sq. ft., including the weight of the insulating earth fill and of a possible snow cover of 6 or 7 ft. The walls are treated as slabs hinged on the top and the bottom and are reinforced for the most unfavourable conditions of loading. No expansion joints were provided in any part of the roof and floor slabs or in the walls, all structural parts being reinforced safely to take the stresses induced by the expected considerable temperature changes. Construction joints were made along lines of zero shear, and oil-stops, similar to those at the bottom of the walls, were placed across these joints. The only expansion joint in the whole structure is at the pump house, the brick superstructure of which would seriously suffer owing to the movement of the reservoir walls, upon the coping of which the house is built. The most important problem in the construction of the reservoir was properly to determine the concrete mix with the given aggregates, and a careful study of all conditions led to specifying a concrete having compressive strength of 3,000 lb. per sq. in. in twenty-eight days. The mix was substantially 1 : $1\frac{2}{3}$: 3. Samples made in the field, when tested in the laboratory, showed a compressive strength of 2,960 lb. per sq. in. in twenty-eight days. To test the oil-proofing quality of the concrete, a test box, 3 ft. cube, with side walls 9 in. thick, was poured on the first day of making concrete. This box, thirty days after pouring, was filled with oil and subjected for five days to a pressure equivalent to 27 ft. head, or 50 per cent. more than that possible in the reservoir. After the box was broken up, it showed no appreciable trace of permeation, so that the originally contemplated coating of the inside of the tanks with sodium silicate was abandoned as unnecessary.



GENERAL LAYOUT OF OIL RESERVOIR AT THREE RIVERS, QUE.

CORRESPONDENCE.

Reinforced Concrete Roads.

SIR,—Mr. Butler, in his letter which you published in your May issue, considers that standardisation of reinforced concrete construction at the present stage would be a mistake. In this I agree with him, but I am at variance with some of his other statements. The use of single-layer mesh with the reinforcing bars to all intentional purposes in one direction only, laid either transversely or longitudinally in the road, is not done for any scientific reason, but because there are difficulties inherent in the manufacture of single-layer mesh giving equal reinforcement both ways. Such meshes may have their value in reinforcing concrete slabs spanning between two girders where the stress can be located in one direction, but they are misused in applying them to road or other foundation slabs unless one mesh be superimposed at right angles to another, at admittedly extra cost in material and labour. The main point is that the reinforcement used should be suitable for the purposes intended. Mr. Butler says that " no case has yet appeared to show " that single-layer reinforcement laid near the bottom of the concrete, with the bars mainly longitudinal, has been known to develop longitudinal cracks. In a report issued several months ago by Mr. Stead, County Surveyor for Somerset, is given an instance of a main road constructed by him in concrete, part of which was reinforced with such material as Mr. Butler advocates laid longitudinally. This particular section cracked along the centre line of the road, and the crack opened so wide that it required to be asphalted. The importance of the successful and economical construction of roads in this country and the part that reinforced concrete roads will undoubtedly be called upon to bear, provided they are scientifically constructed, is my excuse for writing this letter.

J. H. WALKER.

SIR,—Dr. Faber, in his paper on " Concrete Roads " which appeared in your May issue, complains of the price of mesh reinforcement as against the cost of laying plain rods. His figures of £50 per ton quoted are misleading, and not fair to those who sell a high-grade reinforcement at prices that more than compete with plain rods when the cost of placing them correctly in position in the concrete is taken into account. Such reinforcement can now be obtained at £28 per ton.

I am also of opinion that in a great many cases insufficient reinforcement is employed in road foundations to develop the full value of the concrete—this is possibly due to a faulty specification that has been followed by engineers in this country.

ARTHUR W. C. SHELF,

[***In reference to our correspondent's last paragraph, an excellent " Suggested Specification for Concrete Roads " has been issued by the Concrete Utilities Bureau, of 35 Gt. St. Helens, E.C.3, from whom copies may be obtained gratis.—ED.]

SIR,—Replying to Mr. Butler's letter in your May issue, in which he takes exception at this stage to standardising reinforced concrete road construction, and states the B.R.C. specification, which is based partly on American practice, has been generally adopted in this country. No doubt this suits his firm from a commercial standpoint, and has given fairly satisfactory results. My contention is that far better results would be obtained if it were dealt with by a committee of experts. We have a specification of our own for roads, but at the same time it is, no doubt, open to improvement.

A few important points should be settled by a Committee as suggested above, and these are as follows :—

(1) Sufficient area of steel to develop the full value of the concrete.
(2) Type of mesh—square or longitudinal.
(3) Proper position for the steel in the concrete.
(4) Where it is essential to use double reinforcement for certain subsoils, especially where traffic is exceptionally heavy.
(5) Expansion joints.
(6) Method of laying the concrete to produce homogeneity with the reinforcement and prevent initial set between the layers of concrete.

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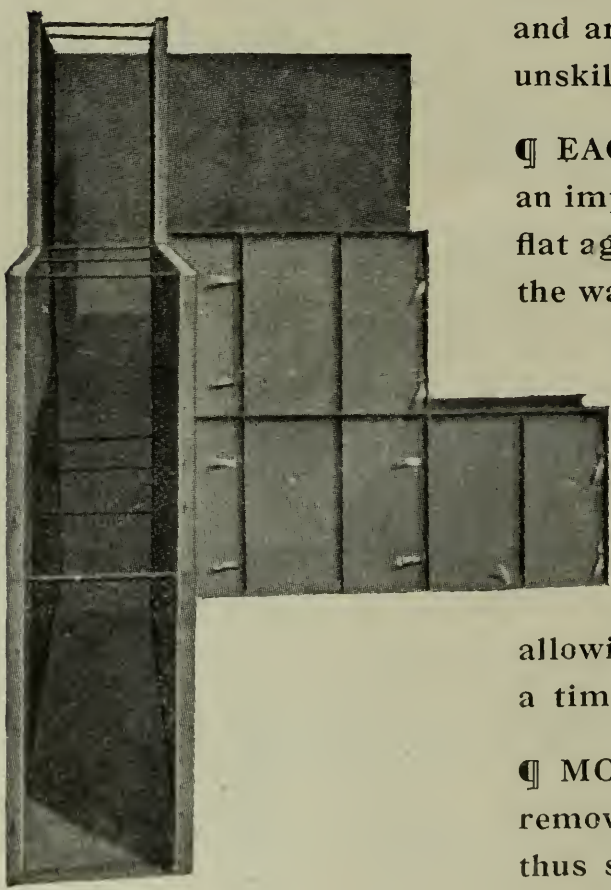

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G.12.

MEMORANDA.

Professional Announcement.—Mr. J. Edward Rowlands, M.S.A., Lic. R.I.B.A., architect and surveyor, late of 20 Exchange Street East, Liverpool, intimates that the working arrangement existing between Mr. Edmund Ware, architect and surveyor, of the same address, and himself is discontinued, and he will continue in practice at 10 North Crescent Chambers, 3 Lord Street, Liverpool (Telephone, Birkenhead 503 and Central 1706).

A Professional Union of Technical Assistants.—We are asked to draw the attention of our readers to the existence of the Architects' and Surveyors' Assistants' Professional Union, which was formed some three years ago for the purpose of raising the economic status of assistants in the architectural and surveying professions, and in the building industry. The Union already has a membership of 1,500, and has done much good work on behalf of the classes for which it caters. The Executive realises the value of social intercourse among those working in the same profession, and during the past winter many pleasant concerts, whist drives, dances, etc., have been held under its auspices, while outings and picnics are being arranged for the summer. The educational side is not neglected, and at an early date the first of a series of lectures of an educational character is to be held in London; on this occasion Mr. G. Topham Forrest, F.S.A., F.R.I.B.A., Chief Architect to the London County Council, will be lecturer. Many assistants in reinforced concrete engineering offices are already members, and others are invited to join. The Secretary is Mr. J. Mitchell, of 36 Victoria Street, Westminster, S.W.1.

Concrete and Plant Growth.—It needs an elastic imagination to connect such a matter-of-fact material as concrete with the wines of France, but, according to a contemporary, there is a prospect that concrete might be an important accessory in the growth of the vine. Experiments in a French vineyard have, we read, shown the remarkable influence of the colour of the soil on plant growth. A light covering of reinforced concrete was spread over the soil, leaving a small uncovered space around each vine. The concrete was painted different colours—one-third white, another third black, and the remainder red. The effect was a prompt increase of temperature in the plots of soil under the red and black coverings as compared with that under the white, and as the season advanced the vines in the colour-warmed soil developed twice as vigorously as those in the soil cooled by the white surface.

"The Empire Municipal Directory."—We have received a copy of *The Empire Municipal Directory and Year Book* for 1922–1923, its fortieth annual issue. This book should be of great service to Borough Surveyors, municipal officials, and all whose business interests bring them in contact with local authorities, containing, as it does, special articles written by recognised authorities on Road Construction and Maintenance, Water Supply and Sewage Disposal, Progress in Public Health, Public Cleansing and Salvage, Housing Progress, Fire Protection, Practical Sanitary Work, Municipal Legislation, etc., besides much other information which will be useful to and appreciated by overseas readers. The Directory includes data relating to local authorities and their officials in England and Wales, Scotland, Ireland, Isle of Man and Channel Islands, and Overseas Dominions. The book (which is published by *Municipal Engineering*, 8 Bream's Buildings, London, E.C.4, price 10*s.* 6*d.* net) is clearly indexed, which facilitates reference.

New Type of Concrete Distributor.—A batch distributor which travels on the forms, spreads the concrete the full width of the slab, and also strikes it off, has, it is stated, been developed by a Chicago firm. The machine, which is specially designed for road work, consists of a trough mounted on a carriage driven by a gas engine. The engine gives the trough a lengthwise reciprocating motion as it travels, shaking the contents even and keeping them mixed. In operation the trough is charged directly from the mixer spout. It then travels to the place where the concrete is wanted and is dumped by being overturned. This piles the concrete in a ridge across the pavement which is levelled down by the strike board as the machine moves back for a new batch.

TRADE NOTES.

Concrete Roads.—It is perhaps only when one sees such a collection of photographs as those in *B.R.C. Roads* (a book issued by the British Reinforced Concrete Engineering Co., Ltd., of Manchester) that the extent to which reinforced concrete roads have been and are now being constructed is fully realized. In this book a very large number are illustrated, both in use and in course of construction, in large towns and in remote rural districts, at home and abroad, and these, of course, only cover the roads in which the well-known " B.R.C." fabric is used. As the publishers state, " nothing is more vital to the industrial and social future of the country than such a scientific method of highway construction as will meet, both from the points of view of economics and engineering, the great demand which is now made upon the roads," and the book will be found interesting not only as an exemplification of the employment

Main Road from Newport and Cardiff: Constructed of Concrete with "B.R.C." Fabric Reinforcement.

of the " B.R.C." system of reinforcement but as a contribution to the literature on the subject of road construction and maintenance. The book, which is well produced on good paper, and which runs to some 160 pp., is a pictorial rather than a descriptive presentation of the firm's products, and is thereby probably the more convincing. In addition to complete reinforced concrete roads, the uses of the firm's products in reinforcing foundations for roads with wood, stone, asphalte, etc., surfaces are illustrated.

Reinforced concrete road foundations are about to be laid in the Surrey Commercial Docks for the Port of London Authority. The reinforcement to be used is " B.R.C., Fabric No. 9," manufactured by the British Reinforced Concrete Engineering Co., Ltd., of Manchester. This work is being carried out by Messrs. J. Mowlem & Co., Ltd., London, S.W.1. At the present time " B.R.C. Fabric " is being employed in reinforced concrete road foundations in three separate Docks.

Messrs. John W. Henderson & Co., of King's Works, Aberdeen, have made arrangements with Mr. F. G. Mitchell, of The Mitchell Conveyor & Transport Co., Ltd., 45-50 Holborn Viaduct, E.C.1, to undertake the manufacture of " Krom " crushers, " Maxecon " mills, and new-type " Kent " mills, for that Company. Messrs. Henderson have also acquired joint selling rights of these machines.

Port of London Authority New Works.—Sir William Arrol & Co. are now engaged in the construction of warehouses and adjacent roadways for the Port of London Authority at King George V Dock ; the reinforcement used on these extensive works is the Walker-Weston double-layer type. The road areas are upwards of 10,000 sq. yds.

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PROSPECTIVE NEW CONCRETE WORK.

ALTON.—*Sewage Works.*—The U.D.C. has decided to apply to the Ministry of Health for sanction to borrow £8,420 for reconstructing the sewage works.

BARMOUTH.—*Sea Wall.*—The U.D.C. has decided to apply for sanction to borrow £5,000 for the construction of a sea wall and promenade.

BLYTH.—*Reinforced Concrete Bridge.*—The Surveyor of the Blyth U.D.C. has submitted drawings and estimate for a flat girder bridge in reinforced concrete at a cost of £2,400, and the Bedlington Council is to be consulted with a view to the work being carried out.

BURNLEY.—*Gasworks.*—An inquiry has been held by the Ministry of Health into an application of the T.C. to borrow £80,000 for gasworks purposes.

CADDER.—*Bridge.*—The Lanark, Stirling and Dumbarton County authorities are considering the erection of a new bridge over the canal near Cadder.

CHORLEY.—*Sewage Extensions.*—Mr. J. D. Watson, Consulting Engineer to the Chorley Sanitary Committee, has reported the estimated cost of the proposed main sewage extension works is £25,000.

CLACTON.—*New Road.*—The Essex C.C. has agreed to the proposal of the Clacton U.D.C. to construct a new road in the district.

CLEETHORPES.—*Bathing Pool.*—The U.D.C. has received sanction to borrow £16,964 for providing a bathing pool.

DARLASTON.—*Sewage Works.*—The U.D.C. has received the sanction of the Ministry of Health to borrow £41,900 for sewerage and sewage disposal works.

DARLINGTON.—*Sewage.*—The Ministry of Health has given its sanction to the Darlington T.C. to borrow £30,000 for sewerage and sewage disposal works.

EAST KIRKBY.—*Reservoir.*—The Ministry of Health has held an inquiry into an application of the East Kirkby U.D.C. for sanction to borrow £15,700 for an additional service reservoir.

ELLAND.—*Sewage.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £29,948 for sewage disposal works.

EFENECHTYD.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Ruthin R.D.C. for sanction to a loan for sewerage and sewage disposal works.

HARTLEPOOL.—*Defence Works.*—The T.C. has decided to apply to the Ministry of Health for sanction to borrow £8,000 for building a protecting wall in front of a section of the present sea-wall.

LIMEHOUSE.—*Dock Works.*—The Treasury has granted a guarantee of £40,000 to the Regent Canal Co. for improvements at Limehouse Basin.

LITTLEHAMPTON.—*Sea Defence Works.*—The Littlehampton Port Commissioners have made an appeal for financial assistance, to the various local authorities concerned, towards carrying out repairs to the river and sea defence works at Littlehampton. The estimated cost is £50,000.

LOWESTOFT.—*Sea Defence Works.*—The T.C. has received the approval of the Ministry of Health to borrow £45,000, for works of sea defence and esplanade improvement on the South Shore, and £6,900 for the reinstatement of the sea wall and the construction of a groyne on the North beach.

MACCLESFIELD.—*Sewage Works.*—The T.C. has received the sanction of the Ministry of Health to construct humus tanks at the sewage disposal works, at an estimated cost of £3,100.

MANSFIELD.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the T.C. for sanction to borrow £14,800 in connection with the extension of the sewage disposal works.

MICKLEFIELD.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application of the Tadcaster R.D.C. for sanction to borrow £7,800 for sewerage and sewage disposal works in Micklefield Parish.

NAIRNSHIRE.—*Bridge.*—The Nairnshire C.C. has instructed the County Road Surveyor to prepare estimates of the cost of rebuilding the Fornighty bridge.

NORTHAMPTON.—*Road.*—The R.D.C. has appointed a Sub-Committee to meet the Northampton T.C. with reference to a scheme for the construction of a new road from St. Andrew's Road to Kingsthorpe, at a cost of £84,730.

OUGHTERSIDE.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Cockermouth R.D.C. for sanction to a loan for sewerage and sewage disposal works at Allerby and Oughterside.

OXTON.—*Water Supply.*—The Southwell R.D.C. has decided to apply to the Ministry of Health for sanction to borrow £23,500 for water supply works.

PURBROOK.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Havant R.D.C. for sanction to borrow £10,500 for sewerage and sewage disposal works, at Purbrook.

SHEFFIELD.—*Reservoir.*—The Water Committee has recommended that the construction of the Wadsley service reservoir, at an estimated cost of £60,000, be proceeded with.

SHEFFIELD.—*Road.*—Application has been made to the Unemployment Grants Committee and to the Ministry of Health for a grant towards the cost of constructing a new road between Owlerton and Firth Park, at an estimated cost of £70,000.

SOUTH ELMSALL.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the R.D.C. for sanction to borrow £12,000 for the extension of the South Elmsall sewage disposal works.

TILBURY.—*Floating Stage.*—The Port of London Authority has received the sanction of a Parliamentary Committee to spend nearly £1,000,000 for providing further facilities for passenger traffic, and constructing a jetty 2,000 ft. long and 80 ft. wide.

WAKEFIELD.—*Sewage Works.*—The City Council has resolved to apply to the Ministry of Health for sanction to borrow £88,000 in connection with the Calder Valley sewage works.

WORKINGTON.—*Dock Works.*—A scheme has been prepared for the development of Workington Dock, at a cost of from two to two and a half million pounds.

YATE.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the R.D.C. for sanction to borrow £4,500 for sewerage and sewage disposal works at Yate.

TENDERS ACCEPTED.

EAST SUFFOLK.—*Concrete Bridge.*—The East Suffolk County Council has accepted a tender of £750 for the construction of a reinforced concrete bridge at Needham Market.

FAILSWORTH (LANCS.).—*Culvert.*—The tender of Messrs. J. J. Middleton & Co., Ltd., of Shaw, near Oldham, for the construction of a brick and concrete culvert, has been accepted by the Failsworth U.D.C.

HINDLEY.—*Humus Tanks.*—The Hindley U.D.C. has accepted the tender of Mr. J. J. Blackburn of Winton, Manchester, for the construction of reinforced concrete humus tanks at the Sewage Works.

LEAMINGTON.—*Bridge.*—The Leamington Town Council has accepted a contract, amounting to £11,432, for the erection of a reinforced concrete bridge over the river Leam.

OXFORD.—*Bridge.*—The Oxford City Council has accepted the tender of Messrs. J. & W. Stewart, London, at £7,968 18*s.* 11*d.*, for the rebuilding of Pacey's Bridge.

REDDITCH.—*Concrete Bridge.*—The Redditch Urban District Council has accepted a tender for the erection of a ferro-concrete bridge over the river Arrow, at an estimated cost of £3,300.

STOCKPORT. — *Sewage.* — The tender of Messrs. D. Eadie & Co., at £19,531, for the extension of the Stockport sewage disposal works, has been accepted by the Sewage Outfall Committee.

WHITBY WATER WORKS.—*Concrete Reservoir.*—The tender of Messrs. H. Arnold & Son, Ltd., of Doncaster, for the construction of a reinforced concrete reservoir holding half a million gallons, at £3,357, has been accepted by the Whitby Water Works Co.

RECENT PATENT APPLICATIONS.

154,152.—Messrs. W. S. Barrie and L. Chadwick: Aromatic hydrocarbon cement.

155,262.—C. M. Eberling: Machines for making blocks and tiles from cementitious material.

159,209.—C. van Driessche: Collapsible cores for concrete construction.

168,847.—K. Winkler: Process for rendering cement, mortar and concrete waterproof.

174,067.—R. Loman: Method of erecting blocks of buildings.

177,212.—Messrs. K. N. Hajgaard and S. Schultz: Manufacture of concrete slabs.

177,229.—W. Wilkie: Apparatus for moulding concrete blocks and slabs.

177,294.—J. Skorkovsky: Manufacture of reinforced concrete tubes.

177,350.—Messrs. H. A. Hamilton and F. J. Twigg: System of building walls.

177,593.—J. J. S. Barker: Hollow building blocks.

177,684.—Messrs. G. Jackson and W. W. Hickman: Metallic bars for the reinforcement of concrete.

177,814.—E. C. R. Marks (Aktiebolaget Lêan): Machines for making hollow concrete building blocks.

177,829.—Messrs. J. L. Whatling and S. Wrigley: Automatic concrete block and slab-making machine.

177,977.—J. Southall: Machines for mixing concrete.

177,991.—J. Thewlis: Machine for making concrete slabs and blocks.

178,163.—A. H. Morle: Reinforced concrete pre-cast bracketed pier system of building.

178,368.—P. J. Myles: Ferro-concrete.

178,370.—Messrs. J. T. Browne and W. Black: Moulding concrete building blocks.

[*Mr. Leonard Stokes, PP.R.I.B.A., Architect.*

GEORGETOWN CATHEDRAL DEMERARA.

(*See page 431.*)

[This Cathedral, which is being constructed of reinforced concrete, is now nearing completion.]


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July, 1922.

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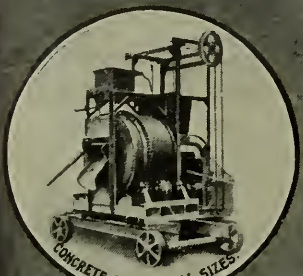

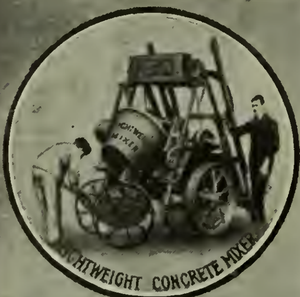

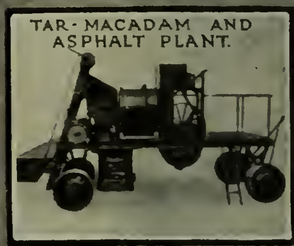

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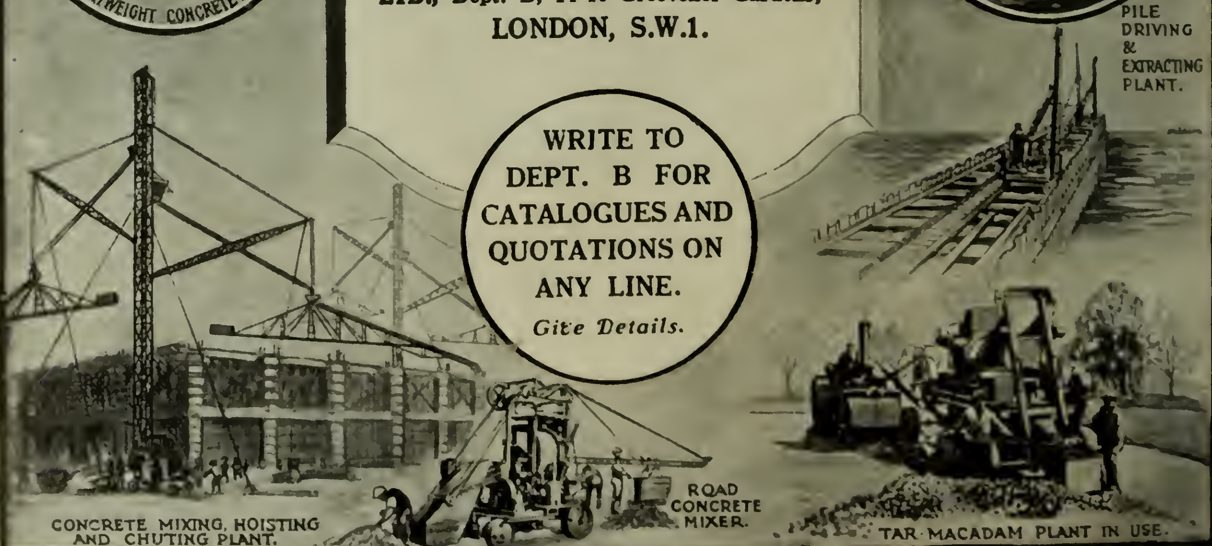


CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 7. LONDON, JULY, 1922.

EDITORIAL NOTES.

COLOUR DECORATION FOR BUILDINGS.

In our last issue we briefly referred to the competition held by the Royal Institute of British Architects for a London building with an elevation in colour, and expressed our disappointment that so little enterprise had been shown by the competitors in departing from the beaten track of marble, terra-cotta, tile, etc. At the present time, when the claims of economical building and the movement for a "brighter London" are so much to the fore, we have no hesitation in returning to a subject which is of importance from the point of view not only of the architect, but also of the general public who have to "live with" the buildings. It is probable that if it were not for the smoke and soot with which all urban buildings become covered almost as soon as they are erected the question of colouring buildings would not have arisen, but it appears doubtful whether any radical reduction in the amount of smoke emitted from factory and domestic chimneys will be achieved during the lifetime of the present generation. It seems desirable, therefore, that the introduction of something more cheerful than the grimy buildings which have for so long depressed the town-dweller should receive serious consideration, and we welcome the present tendency in this direction. But, granting the desirability of achieving the end in view, it is necessary to consider the means not only from the æsthetic but also from the financial point of view. The painting of buildings in colour has been advocated, and tried in Oxford Street, but the frequent renewal of the paint which is necessary makes this an expensive method; the merits of limewash are now being put forward, but the same objection is applicable, for although limewash is cheaper than paint, its annual renewal on a tall building would be a costly matter. Any treatment which requires frequent renewal will undoubtedly be ruled out on the ground of cost, and it is, we think, rather in the direction of keeping clean permanent materials that the practical solution of the problem will lie. In the recent competition, in the majority of the 170 designs submitted, the colour effect was obtained by adding a covering of marble or terra-cotta to an already structurally sound reinforced concrete building, but these materials entail a recurring expense for washing down, if they are to be kept clean in the London atmosphere, in addition to the heavy initial cost. If only clean buildings were required, one need hardly look farther than the steam-cleaning process, which has effected such wonderful transformations on previously soot-begrimed buildings. But those qualified to judge public taste are, as we think rightly, urging the desirability of colour in our streets, and it would seem that a material with which it is possible to erect a structurally-sound building and which, without additional expense or any superfluous covering of costly material, will have a surface of a pleasing colour, is the ideal solution. The only material suitable for the construction of large modern buildings is reinforced concrete, and we are convinced that it is only because its artistic possibilities are not well known in this country that concrete is not generally used for the excellent colour effects which can be obtained by a judicious use of aggregate. In our last issue we illustrated the "Hide and Leather Building," Chicago, the tallest reinforced concrete building in the United States of America, where the architectural expression was chiefly obtained by the use of carefully-selected aggregate, and this month we give a view of a large concrete public building in Austria, where effect has been secured in the same way; it is significant, however, and a sign that there is but little knowledge of this aspect of concrete in England, that in only two out of the 170 designs submitted in the R.I.B.A. competition was it proposed to produce the colour by means of concrete made with coloured aggregates. Concrete can never take the place of marble—nobody wants it to; each is pre-eminent for its own special purpose, and while (since it is too expensive to be used as a structural material) the modern purpose of marble is decoration, the purpose of concrete is the construction of buildings. And as concrete can, at practically no extra cost, be given a coloured and attractive texture, there appears to be no reason whatever why it should be covered, or painted, or limewashed, or hidden at all. Is it not time that concrete was frankly accepted as the building material of the future, as it inevitably must be, and attention directed more to evolving a style expressive of so plastic a material, and in which colour might very well have its place, rather than to disguising it with other materials? If spans are built in concrete which could not possibly be constructed with any other material, surely it is a sham—and therefore bad art—to clothe them with stone or marble, which could never be obtained in sufficient size to form such a span, in a grandiose attempt to acclaim the building as being what it is not? If, as is generally admitted, colour is desirable, would it not be obtained more cheaply, and at the same time with a greater adherence to the chief principle of architecture—truth—by using a concrete formed of an aggregate which looks well when exposed, and keeping it clean either by washing down or by the steam process? We know of no building erected on this system in London, although it is common in America and on the Continent, but an excellent little brochure on the subject, in which the various methods of exposing the aggregate and some illustrations in colour are given, is published (gratis) by the Concrete Utilities Bureau, of 35, Great St. Helens, E.C.3.

THE USE OF CONCRETE IN GERMAN ARCHITECTURE.

A STUDY of foreign contemporary architecture reveals an extensive use of concrete for manifold purposes, with beautiful results. In England a certain impetus was given to concrete by the post-war housing shortage, and its economical advantages were fully proved; but, unfortunately, so much energy was concentrated on this aspect of the matter that the necessity for building beautiful houses as well as cheap houses was often overlooked. Consequently the claims of concrete are still apt to be ignored since its possibilities are not realised. In order to give greater prominence to these possibilities, we have during the past months shown examples of American domestic work of all kinds, but America is by no means the only country whose work may be studied with advantage.

On page 437 of this issue we give an account of a large concrete building in Salzburg, which is illustrated on page 438 this month. Here we see concrete turned to a very different purpose from that to which we are accustomed in England, where, if the concrete be not masked under a veneer of stone, it is left unadorned as a vast harsh-surfaced gridiron of supports and floors. This building is typical of many to be found in Austria and Germany, where concrete is used as a matter of course for any or all the purposes for which it is so eminently suitable. Germany is now articulate with its own modern architectural style, and while there are local influences at work, a certain similarity of thought and feeling is to be observed all over the country. The development of concrete has helped to form this style. Although most of the idiom is traceable to classic prototypes, the use of the orders has almost passed away, and this may be partly accounted for by the fact that engaged columns are ill-expressed in concrete. In many buildings there is a marked verticality almost suggestive of a kind of archless Gothic. This treatment is often met with in shops and warehouses. Other buildings rely on surface, proportion, contour, and a small amount of applied ornament, often cast in concrete. The plasticity of concrete is one of its features that is most readily turned to good account, as in the bold sweep of a staircase, or in the curve of a balcony, and in the many castings, such as garden seats and ornaments, chimney-pots, balustrades, vases and the like.

For many years the only foreign architectural ideas that have penetrated our insularity have been American. Those who are in a position to predict in these matters anticipate, for the near future, an influx of influences from Holland and Germany. Should this prognostication prove to be true, we shall look with interest to a more intelligent interpretation and development of the potentialities of concrete.

THE NECESSITY FOR SKILLED WORKERS.

Commenting on the cause of cracks developing in a concrete bridge in Illinois, which necessitated subsequent repairs, a Canadian contemporary says: "It is becoming more and more apparent that it is not sufficient to have only a good construction superintendent on the job, but skilled labourers are necessary to ensure the proper selection and mixing of the ingredients of the concrete. While the specified proportion of sand, aggregate and cement may have been put in a piece of concrete, if the aggregate and sand have not been selected with great care and the whole mixed together thoroughly, a very poor quality of concrete may be the result. This was noticeable in the spandrel columns of the bridge, which were of a decidedly poor quality due either to the mix or the spouting methods employed. This fault would very likely have been avoided by the use of labourers skilled in this branch of the work." It is generally realised in this country that concreting, both mixing and placing, is an operation requiring care and skill if the best results are to be obtained, and contractors frequently go to considerable trouble to get the right men, but the remarks of our contemporary again emphasise the desirability, which we have often pointed out, of forming an organisation through which expert concreters may be obtained. As is indicated by the work of the Industrial Council for the Building Industry in forming apprenticeship schemes throughout the country, there is a movement in the direction of the better education of the workers, and the time seems opportune for putting into operation, or at any rate carrying a step further, the proposals which the Concrete Institute is considering for the training of operatives for the concrete industry.

THE PERMANENCE OF CONCRETE.

WHO, in erecting a building of a permanent character, takes into consideration how much it will cost his heirs to demolish when it becomes obsolete, or how much someone in a future generation will receive for the materials ? And yet we find a correspondent in a contemporary, apparently seriously, arguing against the use of reinforced concrete because he has lately been " conjuring up visions of London becoming a city of derelict ' Jezreel Towers,' because of the introduction of reinforced concrete buildings. Either by fire, explosions, or by becoming obsolete, and other causes, these buildings will be in the way sooner or later, and who can bear the cost of demolishing and clearing such rubbish ? "—and from this he deduces that " reinforced concrete will ruin the land it stands on ! " If our contemporary's correspondent is logical, he would no doubt wish to see our towns built of the very cheapest and flimsiest materials so that their value as properties for demolition will the sooner be available, and no doubt he would buy the cheapest and nastiest motor-car in order that it might the sooner bring him some return as scrap-iron ! Does he not agree that " a thing of beauty is a joy for ever " ? And surely a freak building such as " Jezreel's Tower " cannot be compared with a modern commercial building. To build with an eye to the value of the materials when the structure is demolished is the very antithesis of the principles of the art of architecture, for it is the permanence of building which gives architecture its pre-eminence over the other arts. Providing the buildings are well designed and a credit to their architects, as, we think, the majority of large modern buildings are, what objection can there be to them remaining so long as they will hold together ? Are common sense and business necessities not to be considered ? Would the writer of the letter object if the masterpieces of Ancient Greece had still been in the same condition as when built ? He could hardly have advanced a better argument in favour of reinforced concrete construction than its durability, an argument which all who advocate its use put in the forefront of their claims on its behalf. In fact, we are inclined to think he is very much interested in furthering the claims of reinforced concrete, and intended his letter as a back-handed compliment !

GEORGETOWN CATHEDRAL, DEMERARA.

By W. L. SCOTT, A.M.Inst.C.E.

The character of this building, as well as the fact that it is constructed throughout in reinforced concrete, makes it very interesting to both architects and engineers who are desirous of keeping in touch with modern building progress.

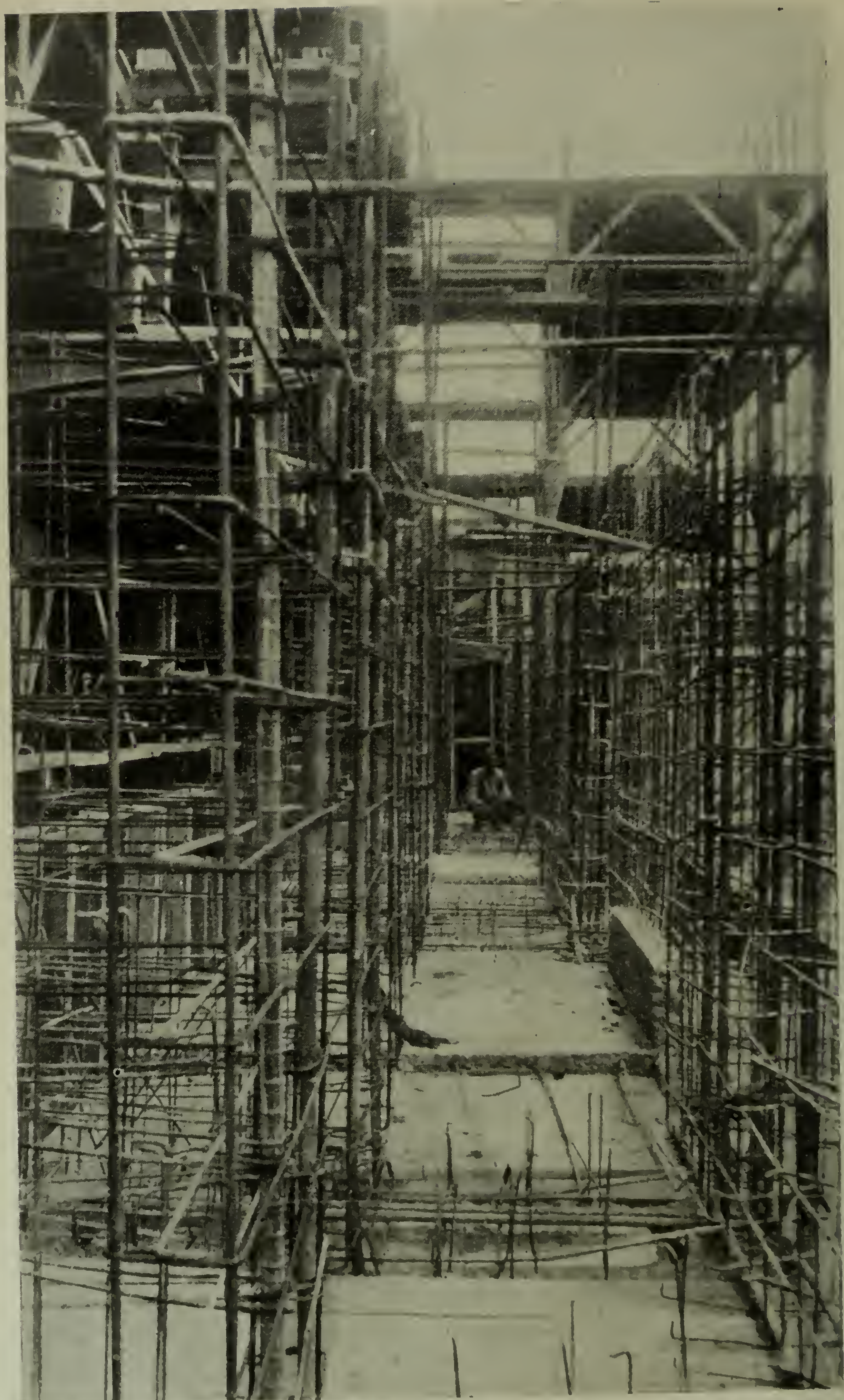
The Cathedral was designed by Mr. Leonard Stokes, PP.R.I.B.A. The erection of the main structure, which is now nearing completion, was commenced in 1914, and, in common with all buildings not directly connected with the war, it was considerably delayed. The whole of the building, including the tracery windows, transoms, mullions, arched vaults, piers, and other moulded work, is entirely composed of reinforced concrete, the whole of which rests upon a rigid cellular raft of the same material. For this, and for other reasons mentioned below, the work may be regarded as unique, even when compared with structures of a similar nature in this and other countries.

The suitability of reinforced concrete for such a building was carefully considered by the architect, and it is pleasing to note that, in view of the opposition of many architects to the use of this material, so eminent a member of the profession should have had the initiative to experiment architecturally on such a large scale in reinforced concrete. The building, however, has justified Mr. Stokes's decision, from both the structural and æsthetic standpoints. The style of architecture chosen lends itself admirably to treatment in reinforced concrete, and no difficulty was experienced by the engineers when detailing the work in arranging the reinforcement so as to maintain all the features of the style desired by the architect.

When it is borne in mind that the tropical climate of British Guiana varies from extreme dry heat to a comparatively long rainy season it will be seen that the weathering properties of concrete constituted another very material factor in favour of its adoption. The life of a timber structure in this part of the tropics, unless continually painted, is very short, owing to the attacks of destructive insects and rot, while a structure composed of suitable stone or brick is practically prohibitive on account of the high cost of transport and the difficulty of providing adequate foundations.

The view is often expressed that, taking into account the great care required in the placing of the steel and mixing of the concrete, reinforced concrete should not be adopted for any

Western Porch.
Georgetown Cathedral, Demerara.



Mr. Leonard Stokes, PP.R.I.B.A., Architect.

South Gallery (looking East) before Completion of Floor and Walls.
GEORGETOWN CATHEDRAL, DEMERARA.

Exterior of Confessionals.
GEORGETOWN CATHEDRAL, DEMERARA.

work where skilled labour, the best materials, and the best conditions and supervision are unobtainable, and for such reasons it is interesting to observe that this very complex structure, having considerably more than 250,000 steel reinforcing rods, each to be carefully placed and wired in position, and also having most difficult work of a curved nature, all requiring to be carefully shuttered, was entirely carried out with native labour, only the supervision being European. Most of the men employed were entirely new to this class of work, and had to be trained as the job progressed, especially with regard to the bending and fixing of the steel reinforcement. The setting-up of the very difficult shuttering was greatly facilitated by the natural aptitude of the natives for woodwork generally, many of the carpenters being very skilled craftsmen.

The Cathedral has been constructed upon the site of an old timber building which was destroyed by fire, and the ground (like most of the coast-line in those parts) is composed of waterlogged silt, capable of sustaining only the very lightest of working loads. The whole structure was therefore designed to rest upon a cellular reinforced concrete raft, which is 5 ft. deep, and covers an area of rather more than half an acre.

One of the principal difficulties met with in designing the foundations to be carried on material of this kind is the very large area required to be in contact with the ground, and also the necessity for guarding against the possibility of unequal settlement. The latter danger has, in the case of this building, been eliminated by equally distributing its weight over the whole site. In order to do this, openings have been formed in the bottom slab of the raft, in the various parts where the pressure would otherwise have been low, so increasing it over the adjacent portions of the slab in contact with the ground. These openings are so arranged in position and size that the resulting pressure over the whole site is calculated to be a constant figure of something under half a ton per sq. ft. In this connection it should be mentioned that special care had to be taken during construction to carry out the work in such a way that the loading was more or less gradually and evenly applied over the site.

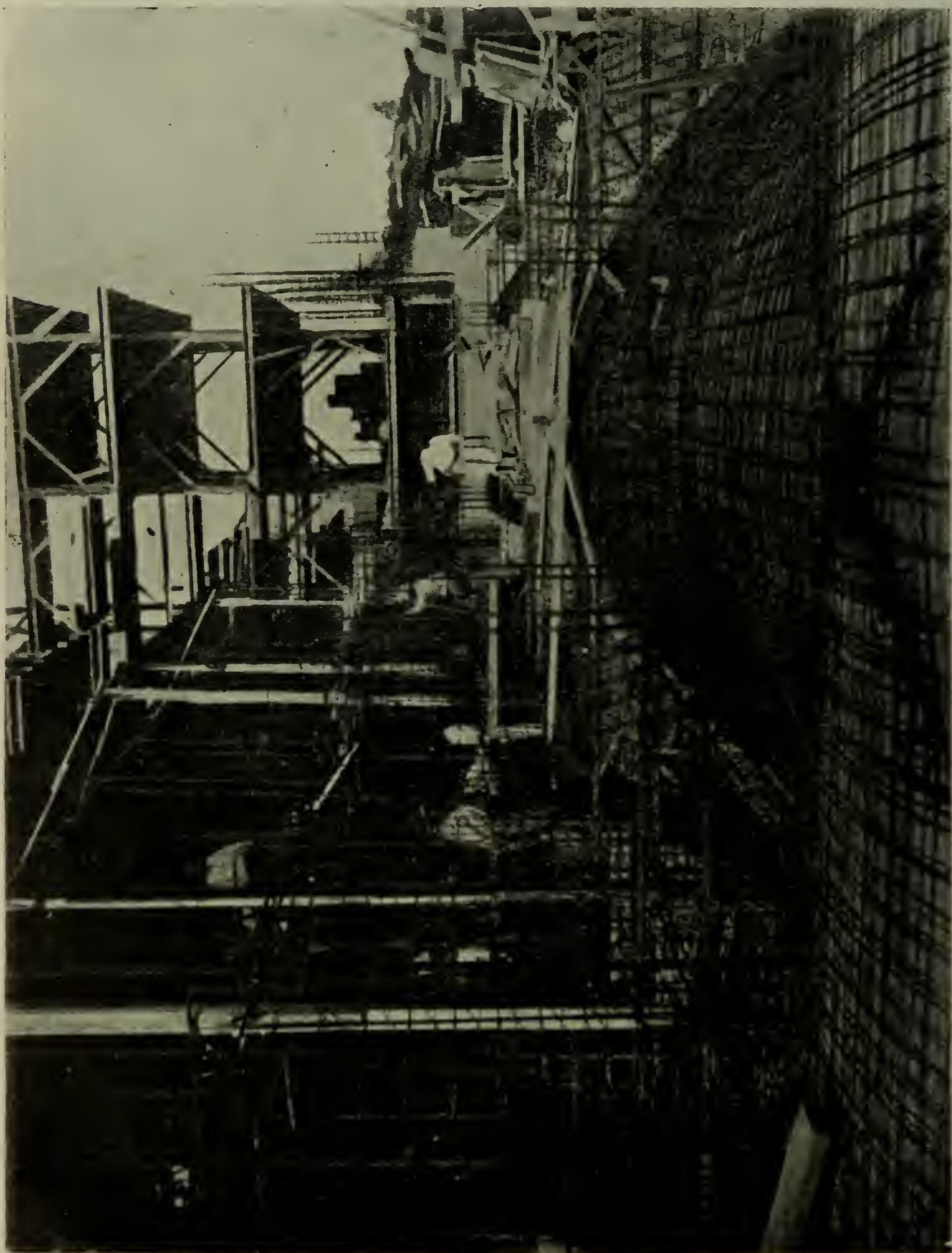
The plan of the building is the usual

cruciform, and the external walls are about 4 in. thick, stiffened by external buttresses.

The nave roof is carried on pillars, in the usual manner, as shown on the drawing on pp. 456–457.

The square tower is also supported by pillars up to the ringing chamber floor-level. Above this level, eight external piers—two at each corner—extend up to the base of the spire. These piers are stiffened by heavy wall beams at the ringing and bell chamber floor-levels, and also at the top of the tower.

The spire, when complete, will extend 90 ft. above the top of the tower. It is octagonal in plan, 30 ft. diameter at the base, and is formed of reinforced concrete slab walls varying in thickness from 6 in. at the base to 4 in. at the apex, stiffened at intervals by reinforced concrete slab diaphragms. This arrange-



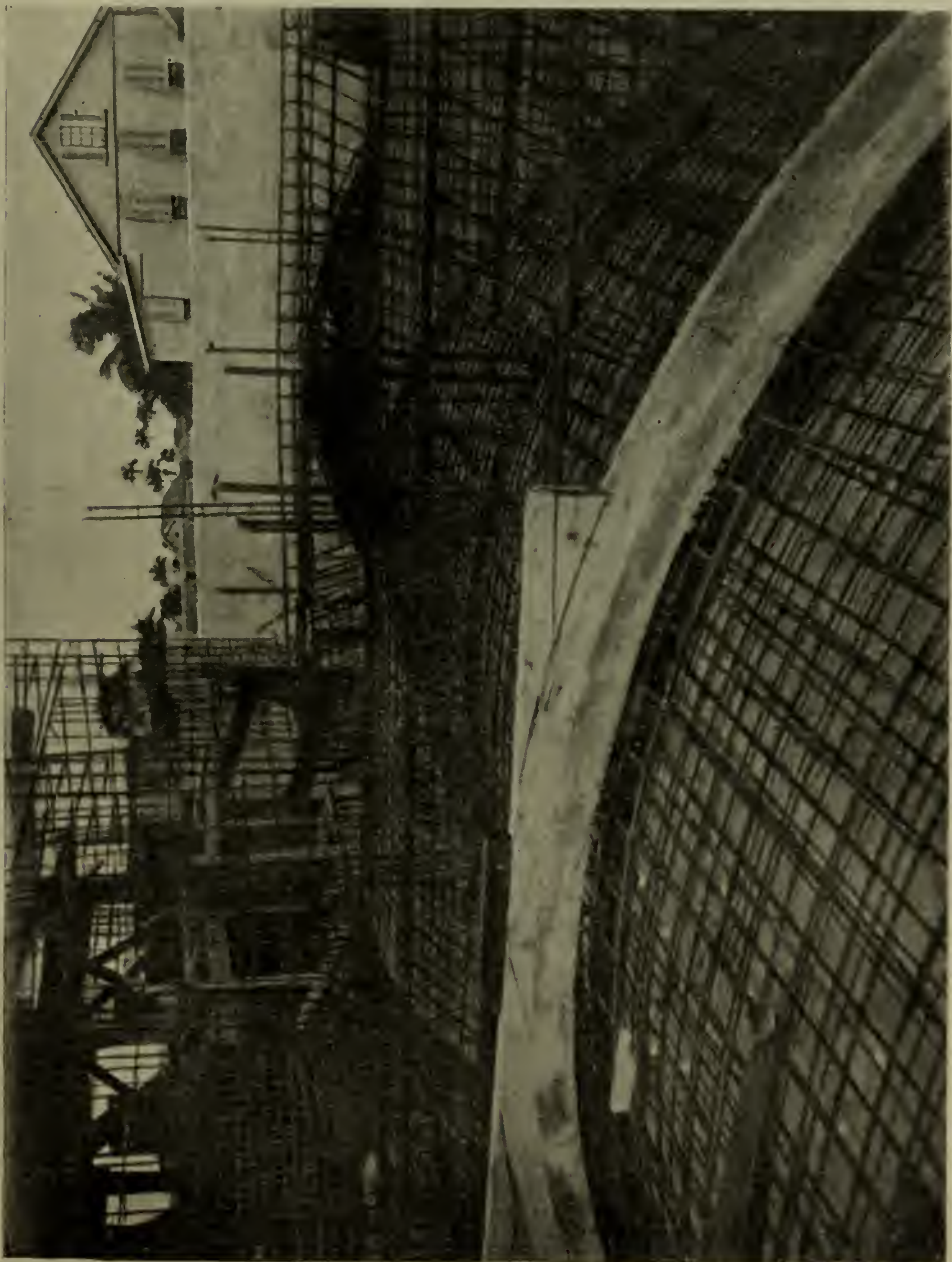
Vaulting to Side Aisles.
Georgetown Cathedral, Demerara.

ment is shown on the drawing on pp. 440–441.

The building is approximately 250 ft. long by 150 ft. wide (overall), and is 220 ft. high from the ground to the top of the spire.

In conclusion, every effort was made in the design to simplify the arrangement of the steel reinforcement as far as possible. Several features, such as arched vaults and Gothic arches, were unavoidably complicated, and it is to the credit of those responsible for the actual construction that these portions of the building were carried out in the same sound and workmanlike manner as the more simple parts, in which the placing of the steel was comparatively easy.

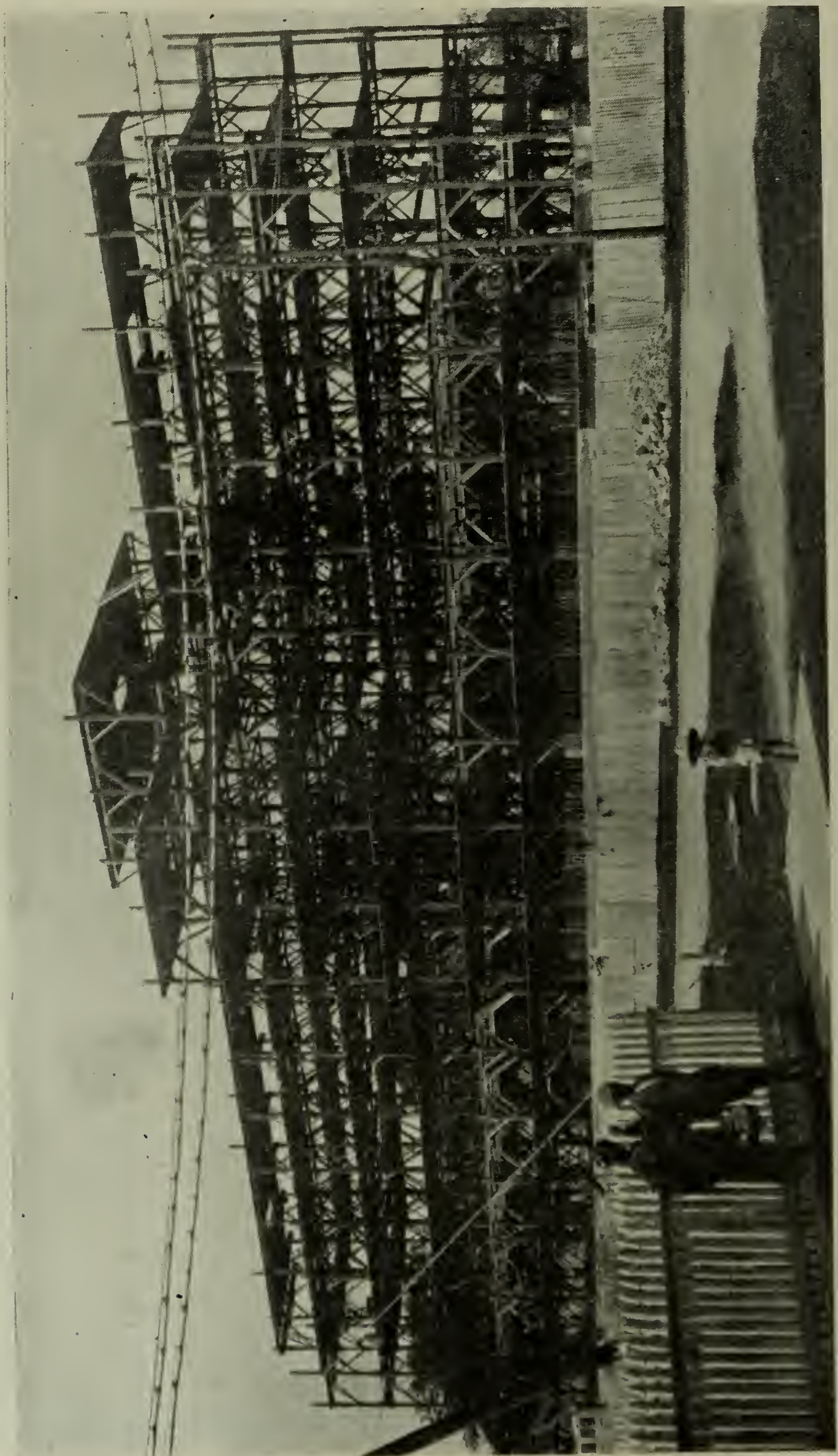
The design and the working drawings of the whole of the reinforced concrete work were prepared by Messrs. The Considère Construction Company, Ltd., of



Intersection of Vaulting of Side Aisles.
Georgetown Cathedral, Demerara.

Westminster, who collaborated with the architect in the preparation of all the necessary details, thereby ensuring the structural efficiency as well as the architectural proficiency of the Cathedral.

The success which has attended this work throughout is a further demonstration of the desirability of collaboration between the architectural and engineering professions, when problems involving the skill of each is necessary to make the structure a complete success.



[Mr. Leonard Stokes, PP.R.I.B.A., Architect.

General View of Temporary Staging.
Georgetown Cathedral, Demerara.

THE MOZARTEUM AT SALZBURG.

By H. J. BIRNSTINGL, A.R.I.B.A.

In revisiting Germany after an absence of fourteen years a change in the architectural tendencies is to be noted; a softening and a refinement seems to have taken place, and the crudities have yielded to a modern virile style which yet has its roots deep planted in the soil of European tradition. While in other branches of art there is a constant interchange of ideas amongst European countries, so that they tend to progress along similar lines, for some strange reason architectural influences find in the Channel a greater obstacle than in the Atlantic, so that, while American architectural influences are apparent in our streets, Continental ideas find here no counterpart. Yet, on the Continent, and in Holland and Germany particularly, a strong epochal style free from the shackles of the orders has emerged. In the early years of this century there appeared to be cause for self-congratulation in the fact that England achieved a comparative immunity from the artistic blight known as *nouveau art* which swept over Europe, pervading every form of craftsmanship with a series of contortions. To-day, however, it seems that this immunity was perhaps not so desirable a thing as it was then thought, for it is this very art form—objectionable as it undoubtedly was—which has helped to produce the present Continental style.

It is generally admitted that with the spread of the Renaissance the architecture which Europe subsequently adopted and still maintains is originally derived from the Greek orders. But just as a language, if it is to remain vital, must constantly undergo changes to meet the new requirements of an ever-changing civilisation, so too must architecture, while maintaining its foothold upon tradition, change and develop with the spirit and form of the age. Contemporary English architecture does not move with the times so much as some critics would like. Its vitality is often sapped with discussions about styles and scholarship. It has become too self-conscious. One of the worst manifestations of this is the failure to deal with concrete as a building material which demands its own particular treatment instead of being covered with a veneer of stone, replete with all the correct classical idioms of column and entablature.

Turning from the general to the particular, the illustration on p. 438 is of a building in Salzburg, which, although actually on Austrian soil, for Salzburg is a few miles over the border, is the work of a German architect and typical of German work. In a certain measure the harmony between the form and purpose of a building is a test of its merit; this building has about it the repose and dignity of a place of learning, and the big portico suggests at once a lecture hall, concert hall, or theatre. Actually all these functions are combined in the building, which, known as the Mozarteum, and built in his native town in memory of Mozart, is an endowed institution for the study of music. The block in the foreground contains administrative offices, class-rooms, practice rooms, and a small concert hall, while the block with the portico is a large concert hall, with cloak-rooms, lavatories, foyer, refreshment bars, etc.

Although in its main lines of pilaster and cornice the building is classical, being, in fact, in the broad European tradition, nevertheless it is not hampered by an obsequious regard for scholarship or an unenterprising preservation of all the classic stock-in-trade. It breaks new ground without distressing any susceptibilities, and it preserves a placid and dignified front worthy of its lofty purpose. There is, however, something even more subtle about its transmutation of old traditions into a new force. Mozart stands out as a very important figure in the history of the little town of Salzburg, and an eighteenth-century flavour, both on his account and from the churches and important buildings, which, for the most part, are of that period, pervades the town, in which a rich profusion of baroque detail abounds. Much softened and refined, these influences are seen on the Mozarteum—in the curved fronts of the flanking pavilions, in the swags and cartouches—forming, as it were, a link with the period of its patron. Yet there is no slavish imitation, and the ob-

THE MOZARTEUM AT SALZBURG.

server becomes pleasantly aware that this building, despite its indisputable modernity, has grown from the past. Within, the designer has made use of, and transmuted, another local characteristic. The district is noted for its wood-carving, and particularly for the production of painted wooden figures, which in addition to finding their way into most of the toy-shops in the world abound in the many wayside shrines and in the churches, and simple, bright, toy-like effects are met with in buildings of every kind. Something of this spirit it is that pervades both the concert halls in the Mozarteum, but particularly the smaller one. Bold, simple, bolection mouldings are employed, and the wall is divided into large irregular-shaped panels; the colours are, for the most part, white and cream and gold, with large expanses of mauve and green. The freshness and brightness of this hall, the happy combination of tradition and originality, make a startlingly new and harmonising effect.

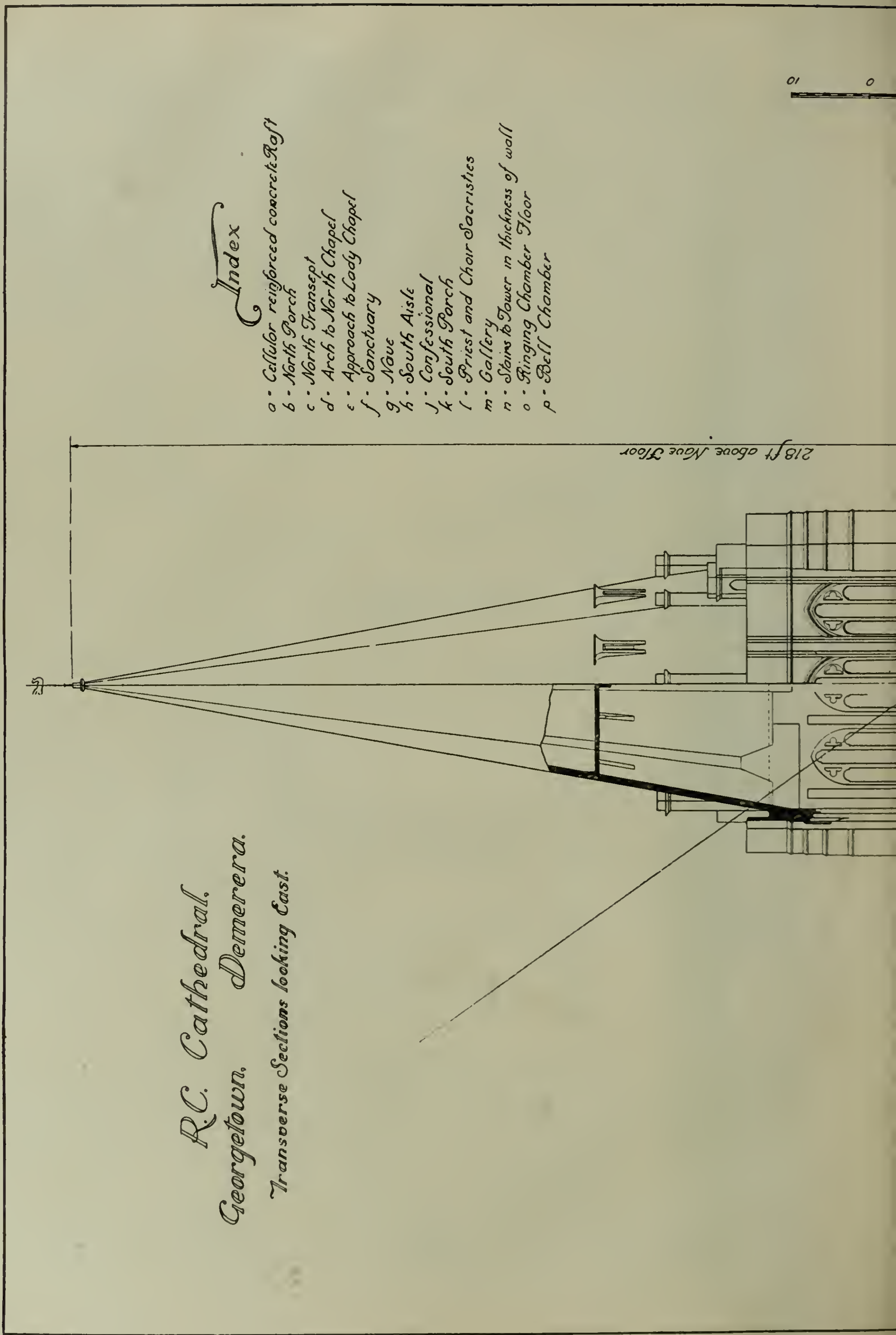
For readers of this journal, however, the chief interest of this building lies in the fact that not only is it constructed in concrete, but it announces this fact to the world by standing triumphant and serene with its surface unclothed in a garb of stone, brick, or any other superfluous covering. It has, in fact, a very delightful surface. A contrast is formed between the plinth and the superimposed building, the latter having an aggregate of slightly finer grain and the surface being whitened. The whole effect of the jointless expanse of wall, broken only by the architectural features, is extremely satisfying. The design, moreover, by reason of its simplicity and formality, is one well suited to a concrete construction.

The building was opened just before the outbreak of the war, and the vacant niches yawning for their morsels of statuary indicate that the final completion has not yet taken place. However, the institution, which is endowed by music-lovers of every nationality, is carrying on its work, and for 600 kronen (a sum which at the moment of writing is worth about 4*d*.) an excellent concert of modern or classical music can be heard from the best seats in the hall on several nights each week.

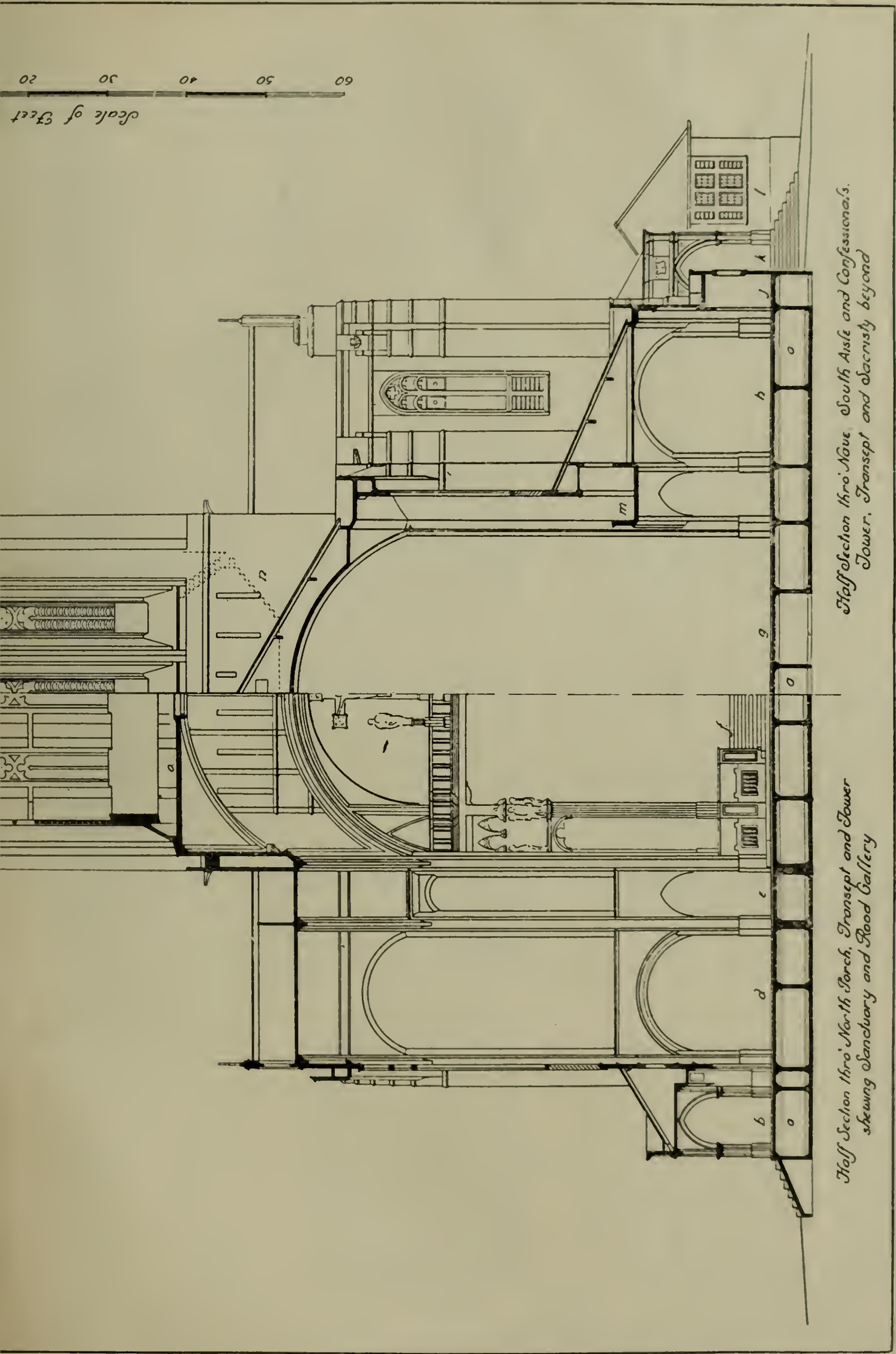
The employment of concrete as an integral part of a building is much more general in Germany to-day than in England. Floors, staircases, balconies, balustrades, terrace-walls and their ornamentations, chimney-pots, garden ornaments, roofs, in concrete are met with in buildings of every class. And a decorative art is made of the concrete; its plasticity is revealed in the bold sweep of cantilevers, in elliptical openings, and there is a certain massiveness about the modelling of a concrete capital which, while lacking the delicacy of fine stone carving, produces an æsthetic effect of its own which we in England have yet to acquire and understand. Certainly in the southern part of Germany in which I travelled the chief materials are brick and concrete, and the use of the latter is extending daily, because of its ease in transport, its greater versatility, and, perhaps, on account of its inherent beauty, which German architects are learning to use to advantage.

The Fire-Resistance of Concrete.

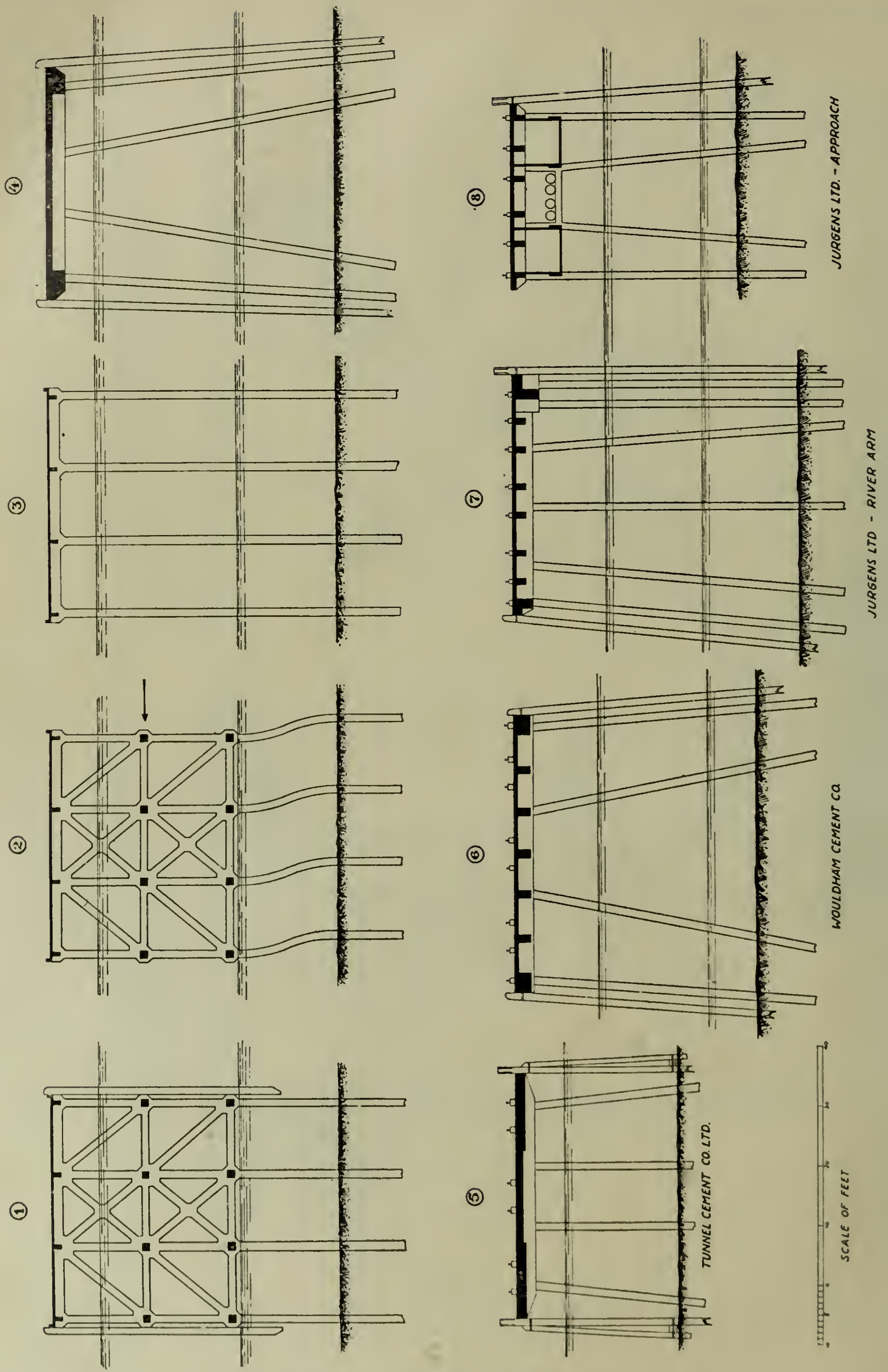
The complete destruction of the contents of a factory building in Berlin in January last is stated to be the first experience of a fire in a large reinforced concrete building in Germany, and the result of the conflagration fully justifies the claims on behalf of the fire-resistance of the material. The building in which the fire occurred was five stories high, of beam-and-girder reinforced-concrete construction, with an area of 255 ft. by 180 ft., and an interior court about 50 ft. by 70 ft. Each of the five floors was open and all were connected by staircases on the interior court. The building was filled with highly-combustible materials. The fire broke out in the basement and rapidly spread over its entire area, breaking through the skylight into the open court, which formed a chimney carrying the flames up to the exposed windows on each floor. These windows were soon broken through and every floor completely gutted of its contents. After the fire it was found that every piece of material that could possibly burn in the building had been consumed, and that only the reinforced concrete structure itself remained. The principal damage to the concrete was the crumbling off of the outer layers of concrete and the exposure of the steel.



Georgetown Cathed



.RA. (See p. 431.) [Mr. Leonard Stokes, PP.R.I.B.A., Architect.



Elastic Concrete Jetties. (*See p.* 443.)

THE ELASTIC CONCRETE JETTY.

By R. N. STROYER, B.Sc., M.I.Mech.E.

REINFORCED concrete has now been in use for a considerable number of years for the construction of jetties and piers, and has proved in almost all respects eminently suitable and successful for the purpose. This article is confined to one particular aspect of the reinforced concrete jetty, namely, its ability or otherwise to absorb shocks and vibrations from vessels moored to it with as little damage as possible to itself and the vessels. This is a point of great importance to the life of a jetty, and has considerable bearing upon satisfactory service. It is not sufficient that a jetty be strong, stiff, and heavy enough to withstand blows and bumping from the vessels using it if its very rigidity and stiffness may cause damage to the ships, which might have been avoided if the jetty had been able to " give " a little in resisting these shocks. Hitherto the timber jetty, and to a smaller extent the steel jetty, have had the great advantage over the reinforced concrete jetty that they were far more elastic and able to absorb shocks than the ordinary reinforced concrete jetty, and it has been the writer's experience on several occasions that clients have refused to consider the building of jetties in the latter material simply because of the uncompromising rigidity of the concrete jetty.

The usual type of reinforced concrete jetty, it must be admitted, gives cause enough for this complaint, and on reference to *Fig.* 1, which represents a typical example of the usual jetty design, it will be seen that the whole upper portion of the cross section of the jetty from the deck and down to the bottom walings forms one stiff and unyielding structure on account of the triangulation effected by the various struts, ties or walings. The whole of this part might be considered, from the point of view of elasticity, as one solid disc or wall, and is in fact intended to act as such, and the only member in the jetty that can possibly " give " to a blow or shock in a transverse direction is the free length of the pile from the bottom waling down to the ground. On the assumption of fixity of the pile at both ends of its free length, the effect of a horizontal force acting on the jetty will be approximately as shown in *Fig.* 2, where the movement is indicated to a very exaggerated scale. It is clear that the extent of movement or " give " for a certain force is dependent on the amount of free length of the piles, the horizontal deflection being a function of the cube of the free length. In other words, there is eight times as much " give " in a pile twice as long, other conditions being equal, and it therefore appears easy enough to increase the elasticity of a jetty by simply making the free length of the piles greater. This is, in fact, one of the main points in the design advocated in this article, but it is not sufficient in itself, and there are other important considerations. A jetty with long piles and no bracing at all, such as *Fig.* 3, would probably be too elastic and unable to absorb the kinetic energy from vessels moving against it unless some means of reducing the movement were introduced. This can be done easily and efficiently by increasing the mass of the decking, and slanting some or all of the piles, as suggested in *Fig.* 4. The blow from a vessel is generally transmitted to the deck of a jetty by a system of fenders so arranged that the piles themselves are not called upon to absorb any lateral blows, and if, by making the deck structure heavier, a sufficient mass is set against the moving mass of the vessel, the resultant movement of vessel and deck together, after the blow, is so reduced as to enable the piles to absorb this movement within their allowable stresses. The slanting of the piles has the effect of introducing some axial stresses in the piles instead of merely bending stresses, and by suitably proportioning the inclination and position of the piles a large range of elastic deformations can be obtained, varying from practically zero to the full bending deflection.

For the purpose of appreciating what is happening to a jetty and its piles when a vessel is moored to it, it may be useful to consider the various ways in which forces may act upon it. Only the horizontal forces are of any interest in this connection, as the vertical forces are easily accounted for and present no more difficulties than those met with in ordinary building work. The horizontal forces will either pull or push the jetty sideways, and there are two ways in which they can act—either as a steady sustained force, such as would result from the action of the wind or tide on the vessel, or as a blow, where the force is applied suddenly and is due to the vessel being in motion, either on account of the swell while moored or in the act of being brought alongside or leaving.

With regard to the action of a steady horizontal force it will be realised that the only factor which counts in this connection is the resistance of the free length of the piles. Each pile can resist a certain bending moment, and if the horizontal forces produce bending only in the piles it is a simple matter to calculate which force, acting on the given free length of pile, will produce the bending moment the pile can take. The greater the free length of pile, the smaller the force that can be taken by it, whether the pile be fixed at both ends or at one end only, the ratio being directly inverse. A 15 in. square pile reinforced with four 1 in. bars, and fixed top and bottom can take about 1,000 lb. at the top with safe stresses if 50 ft. long, this producing a deflection of about 3 in. ; if 25 ft. long it could take about 2,000 lb. with a deflection of $\frac{3}{8}$ in. When the horizontal forces produce not only bending moments but also axial stresses, as in trestles with inclined piles, the case is similar, although the difference between long and short piles is not so pronounced. While for a steady pull or push the main factor is the length of the piles, it will be seen that the mass of the piles or the whole jetty plays no part.

For forces applied suddenly, such as those resulting from moving masses, the case is entirely different. For many reasons, apart from the purely theoretical, it is an advantage if the jetty can move perceptibly during the absorption of the shock, there being less likelihood of damage to either vessel or jetty in this manner. In order to obtain a large amount of movement (or " give ") it is necessary to have a long free length of pile, and this, as we have just seen, means that only a comparatively small force can be taken by the pile. As, however, the work done in absorbing the blow is a function of the force taken by the pile times the way through which it moves, it will be seen that the advantage is distinctly with the long pile, for, with the example mentioned before, the 50-ft. pile moved by a force of 1,000 lb. through its allowable deflection of 3 in. absorbs four times as much energy as the 25 ft. pile moved by 2,000 lb. through a deflection of $\frac{3}{8}$ in. In addition, the small deflection will jar the vessel and the jetty whereas the large deflection will be felt as a more gentle " give." In the case of shock absorption, the mass of the jetty plays a very important part, inasmuch as it is helpful in reducing the kinetic energy to be absorbed by the piles, by the simple means of reducing the velocity of the ship before the blow to a smaller velocity after the blow, determined by the proportion of the mass of the ship and the combined mass of ship and jetty. In a braced jetty the struts, ties, and walings do some good by acting with their weight together with the decking to increase the mass of the jetty to be moved by the ship ; in the unbraced jetty, as the writer is advocating it, the mass is laid in the decking.

Fig. 5a. Tunnel Cement Works, Purfleet : Loading Jetty under Construction.

Fig. 6a. Wouldham Cement Co.'s Unloading Jetty.

It will be seen, first, that it is considerably cheaper to put the concrete in the decking than in the bracing, on account of the ease in placing it ; but the greater thicknesses in the decking also effect an additional saving in deck reinforcement. There is also a saving in time inasmuch as tide work is dispensed with, so that, taking it all round, this type of jetty, the elastic jetty, compares very favourably with the ordinary type from a contractor's point of view. From the designer's point of view it is an advantage to have the heavier thicknesses to deal with, as the placing of tracks frequently has to be altered after the design is finished and the beams laid down, a circumstance which does not mean much trouble where the heavy dimensions make it possible to lay the tracks *ad libitum*. From the owner's point of view, the elasticity of the jetty is a considerable advantage, and helps to lengthen the life of the jetty, and the vessels ; in action, this kind of jetty resembles a timber jetty, where the elasticity, in spite of the usual bracing, is due partly to the looseness of timber joints and partly to the amount of " give " in the timber members themselves. The bracing in a timber jetty is a necessity owing to the impossibility of joining timbers monolithically ; in a concrete jetty, where all the joints can be made monolithic, so that decking and piles form a rigid frame in the true sense of the word, the fixity of the joints does away with the necessity for bracing. In cases where piping, hydraulic transmissions, etc., have to be carried on the jetty a flexible joint will overcome any objection to the elasticity, if excessive from this point of view.

It may be of interest to show a few illustrations of jetties in the Thames, built on this principle and tested through a number of years' service. In 1913 the Tunnel Cement Co., at Purfleet, built a jetty 41 ft. wide by 220 ft. long, which was extended in 1921 to a length of 350 ft. The section (*Fig.* 5) shows a typical trestle with slanting piles and deck slab which is without beams, being 12 in. thick in the middle and 18 in. along the sides. The photograph (*Fig.* 5a) shows the jetty under construction, and is taken at high water so that the length of the piles is not seen. The jetty has to take locomotive and crane traffic and accommodates vessels up to 700 tons displacement.

In 1915 the Erith Oil Works built an L-jetty where the approach and the river arm are on the same principle, with all the piles in the trestles slanting. The jetty carries heavy electric cranes, while it accommodates barges and steamers up to 2,000 tons.

The next section (*Fig.* 6) is that of the Wouldham Cement Company's jetty at Grays, which is 46 ft. wide by 280 ft. long, carries a number of tracks for locomotives and cranes weighing 45 tons and takes steamers up to 5,000 tons displacement. The photographs (*Figs.* 6a and 6b) show the same principle introduced of slanting unbraced piles and heavy decking.

While these three jetties are of moderate size, the L-jetty just built at Jurgens'

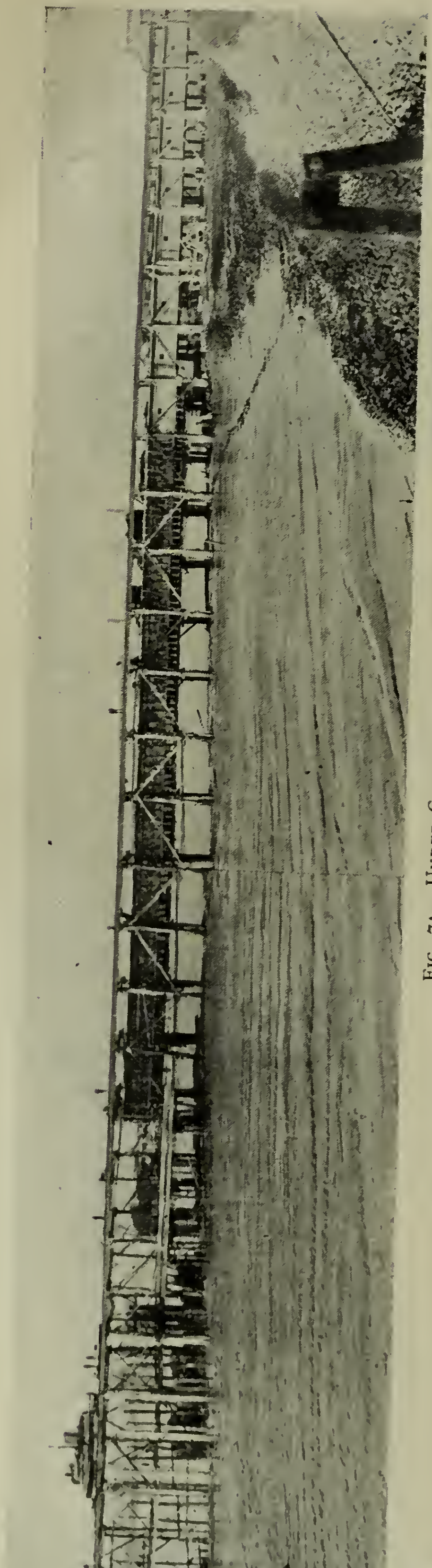


Fig. 7a. Under Construction.

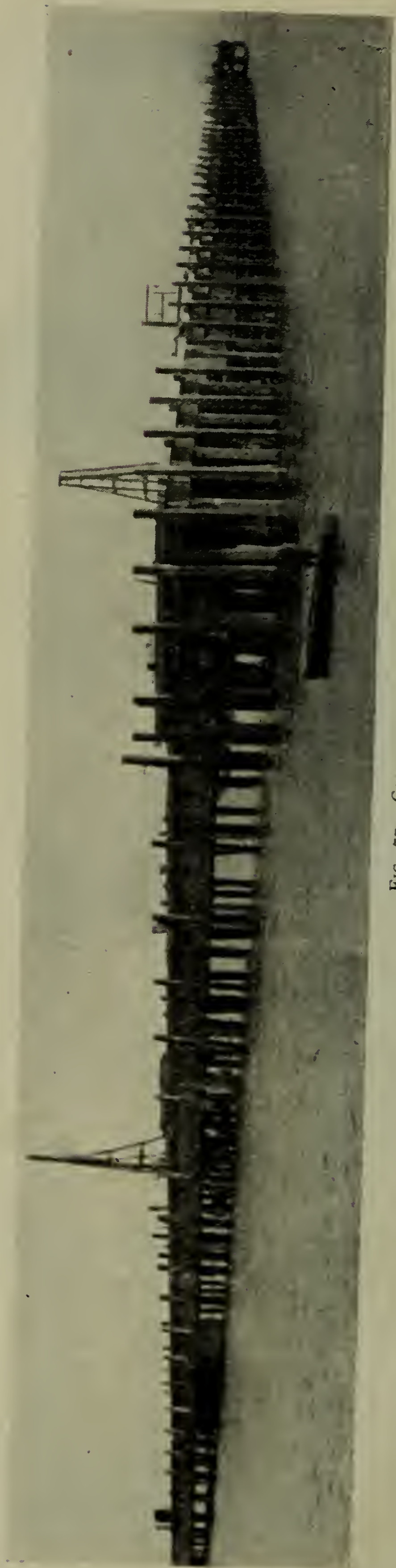


Fig. 7b. Completed.

Jetty at Jurgens' Margarine Works, Purfleet.

FIG. 6B. WOULDHAM CEMENT CO.'S UNLOADING JETTY : VIEW UNDER DECK.

Margarine Works, Purfleet, is one of the largest, if not the largest, in the Thames, having an approach 650 ft. long and 31 ft. wide, and a river arm 525 ft. long and 40 ft. wide, and carrying three standard rail tracks and five large electric cranes, while accommodating steamers up to 15,000 tons. Although the piles are on an average 50 ft. long, there is no bracing of any kind, and the piles, which are partly vertical and partly slanting, carry a comparatively heavy deck (see *Figs.* 7 and 8). On the section of the approach will be noticed two ducts under the deck for carrying conveyors of coal and raw materials, while the photographs (*Figs.* 7A and 7B) show the jetty during construction and in its finished state.

In conclusion, the writer would like to make it clear that there are, of course, limitations to the use of the unbraced jetty ; there may be cases where absolute rigidity is required, and again it may not be convenient, in the case of very great depth of water, to have an entirely unbraced jetty. In the latter case practically the same effect would be obtained by having a free length of the piles of say 40 to 50 ft., which would give sufficient elasticity for ordinary purposes, and use bracing above this length. It is easy to determine the free length of piles required to give a certain predetermined allowable movement of the jetty, and if this has been settled to start with the remainder is a simple matter of calculation.

The Largest Concrete Ship in the World.

WHAT is claimed to be the largest concrete ship so far constructed in Europe has just been launched at Lavagna, between Genoa and Spezzia. Named the *Persivoranza,* the vessel is constructed entirely of reinforced concrete. It is of 4,700 tons displacement, and 3,000 tons burden, fitted with two motors to give a speed of 8 knots per hour, and five auxiliary sails. The designer, Signor Galliquani, has supervised the construction of the vessel at the shipbuilding yard at Lavagna.

THE BRITISH STANDARD SPECIFICATION FOR PORTLAND CEMENT.

By our Special Contributor.

THE present edition of the British Standard Specification for Portland Cement was issued some two years ago, and sufficient time has elapsed to enable it to be discussed in the light of experience.

It may be taken for granted that, apart from the value of standardisation, the prime object of a specification is to ensure that the buyer obtains the material he needs, and this in the case of Portland cement may be defined as a material with (*a*) reasonable setting properties, that is, properties which give sufficient time for mixing and deposition before setting commences, (*b*) satisfactory hardening qualities, implying early development of strength as well as great ultimate strength, and (*c*) stability, or freedom from expansion and disintegration.

So far as setting properties are concerned, the present specification is adequate, requiring as it does that the initial set shall be not less than twenty minutes and the final set not more than ten hours. The method of testing is, however, open to criticism as having an arbitrary and unscientific basis. The initial set, being the time when a needle of certain dimensions and weight fails to penetrate a block of cement mixed under certain defined conditions, merely indicates that the cement has attained a certain degree of stiffness, and does not necessarily indicate the commencement of the chemical action of setting. There is, indeed, good reason to believe that setting actually commences in many cements some considerable time before the initial set is recorded, and hence it is always advisable that concrete should be placed in its final position as soon as possible after mixing.

There is no doubt that the question of determining the setting-time of cement has exercised the Standardisation Committees of many nations, but apparently an arbitrary basis, similar in principle to that in the British Standard Specification, is universal. Probably the most scientific basis in the present state of knowledge would be the rise in temperature of the cement when mixed with water, the initial set being the period elapsing before a pronounced rise in temperature occurs. It is reasonable to assume that rise in temperature synchronises with commencement of setting. For accuracy, it might be necessary to conduct a test of this nature in somewhat elaborate apparatus designed to keep the test piece under conditions of insulation so that it be unaffected by fluctuations in atmospheric temperature and that the heat generated during setting be not dissipated.

While a more scientific test for setting-time would be welcome, the present test, as already stated, is adequate and safeguards the buyer from a cement which begins to set too quickly, or which takes an inordinate time to reach a certain degree of hardness.

Hardening qualities, which form the second fundamental property of cement, are now determined by the tensile strength of the cement at seven and twenty-eight days, both neat and when mixed with three parts of a standard sand. The first question that arises is whether neat tests are of any value, and it should be noted that neat tests are absent from the cement specifications of America and the more important European nations. The argument against neat tests is that they have no practical application, as cement is almost invariably mixed with sand and aggregate. The same argument might, however, be used with equal force against the sand tensile test, because, as now defined, this test is far from being akin to practical usage, the proportion of cement being insufficient to fill the voids in the sand and the latter being ungraded. It will be seen that the real question at issue is whether the cement specification should be designed to show what strength may be obtained in practice or whether it should have, for its foundation, tests based on the knowledge of what may be expected from a properly-manufactured cement. The writer would be sorry to see the neat test disappear, because it reveals certain of the qualities of cement which cannot be seen in the sand tests; moreover, it should be realised that in a concrete the particles of sand and stone are often separated by masses of neat cement of appreciable thickness, and the strength of the concrete depends not only upon the adhesive qualities of the cement but upon its cohesive properties, which are exemplified by the neat tests. It may be urged, then, that neat tests of cement are useful not only as an indication of the care with which the cement has been manufactured, but for the purpose of showing the cohesive powers of the cement, which powers are exercised in the practical application of the cement.

There is, however, one factor in the neat tests requiring consideration, namely, the twenty-eight-days' test. This test is a legacy from the early days of cement manufacture when no satisfactory soundness test existed and consequently engineers deemed it necessary to impose a twenty-eight-days' test with a minimum increase over the seven-days' test in order to obtain evidence as to freedom from disintegrating tendencies. The adoption of a searching soundness test removes the necessity for a twenty-eight-days' test, and it is now axiomatic that a cement complying with the B.S.S. tests is a perfectly stable material without the evidence afforded by the twenty-eight-days' test.

It may be argued that the twenty-eight-days' test is harmless and may be allowed to remain, but in its present form at any rate it is a deterrent to progress, because finely-ground cements naturally develop their strength at an early date and do not therefore show the same increase at twenty-eight days, which is the delayed development of strength of coarsely-ground cements. The consequence is that there is a limit in the fineness to which cement may be ground, simply because the ultra-finely ground cements develop their strength too soon and thereby risk non-compliance with the Standard Specification. This early development of strength is a desideratum from the user's point of view, and ought not therefore to be discouraged by the twenty-eight-days' neat test. It may be well to point out that the early development of strength in finely-ground cements does not imply stagnation at later dates, because while fineness operates to produce strength in the early stages there are other factors in evidence during the course of succeeding months and years, and these produce continuous growth in strength, whether the cement be fine or coarse.

If, however, the twenty-eight-days' neat test is abolished, the cement user must be safeguarded against a poor quality cement which by the help of fine grinding just manages to reach the 450 lb. neat seven-days' test. This safeguard can be obtained by raising the seven-days' neat limit to, say, 600 lb. per sq. in.

Turning to the sand tensile test, it has already been mentioned that this is not in line with practical conditions—first, because the proportion of cement is insufficient to fill the voids in the standard sand, and, second, because the latter is all of one size and not graded. These differences from practice might be removed by making the sand test with a mixture of 2 or 2½ parts of sand to one part of cement, and by grading the standard sand in three different sizes as required by the French Government Specification. Here, again, the limit of the seven-days' sand test might be raised from the present level of 200 lb. minimum to 300 lb. in order to exclude inferior cements.

Experience shows that the ordinary user of cement is as much or even more concerned with the strength or hardness of concrete at an age of one or two days than with its seven-days' strength, and the introduction of a tensile test at twenty-four or forty-eight hours might well be considered. Complaints concerning concrete usually centre around the hardening properties at ages of two and three days, and a tensile test at this period would settle at once the question as to the responsibility of the cement for retarded hardening.

Coming to the third requirement of a cement buyer, namely, stability or freedom from expansion or disintegration, there is no doubt that the existing Le Chatelier test is sufficient safeguard in this connection. There is, indeed, reason to think that it is unnecessarily severe, but as British cement manufacturers as a whole have improved their processes to meet the specification requirements no advantage would be gained by contending for wider limits.

When a cement specification secures the essentials of setting, strength and stability, it may be argued that no further requirements need be enforced. Strictly speaking this is true, and the additional tests specified in the British Standard may be for the purpose of eliciting desirable or interesting information of the general character of the cement rather than for the purpose of attributing any specific value to the possession of certain properties of fineness or chemical composition. Taking the fineness test, for example: fineness of grinding in a cement is only a means to an end—the finer the cement the more are its strength and stability improved. But, if a cement having a residue on the 180 sieve of 3 per cent. or 4 per cent. above the specification limit possesses strength and stability in excess of the requirements, it is illogical to condemn the cement for its coarseness. Here, again, manufacturers have adapted themselves to the specification, and there would be no object in abolishing the fineness tests or widening the limits. The fineness test may be of value in a few cases, such as detecting a poorly-manufactured cement showing the bare strength requirements of the specification and only doing so by reason of extreme fineness.

Dealing with chemical composition, the limitations of magnesia and sulphuric anhydride are necessary to exclude cements of disintegrative tendencies which would not be detected by the Le Chatelier test. The limit to insoluble matter is necessary to exclude adulterants, and the test for loss on ignition is to reveal stale and badly-burnt cements. The restriction of the ratio of lime to silica and alumina is somewhat unnecessary, as slag cements are explicitly excluded, and such restriction may conceivably prevent the development of cement manufacture upon improved lines.

GREAT SANKEY WAR MEMORIAL.

[The whole of this memorial, with the exception of the bronze tablet at the base, was carried out in concrete by the Warrington Concrete and Plaster Co., Ltd., of Warrington. The base and die-block were cast *in situ*, with a hard rough core, and a pink shap granite exterior, reinforced with expanded metal made up into the form of a cage and placed inside the wooden forms, leaving a 6-in. space to be filled with granitic material. The column and cross, of shap granite chippings reinforced with ½-in. mild steel bars, tied at intervals, were cast separately. The total height is 22 ft. The balustrading is of pre-cast blocks of 3 ft. lengths of the same material as the column, while the square balusters are of a finer material, mixed and tamped dry, thus giving a different colour and texture. The concrete, with the exception of the balusters and ball finials, was finished with carborundum stones, which gives a smooth surface with exposed aggregate. The whole of the concrete was mixed by hand, and only best Portland cement used.]

LARGE NEW WATER TUNNEL AT CHICAGO.

By ROBERT H. MOULTON.
(Board of Trade, Chicago.)

One of the biggest triumphs of modern engineering is the mammoth tunnel in the city of Chicago. This tunnel, built at a cost of approximately 4,600,000 dollars, is eight miles long and 12 ft. in finished diameter through the solid limestone 140 ft. below datum. Three miles of the tunnel run under Lake Michigan, from the Wilson Avenue crib to the shore line, and the other five miles from the shore to the Mayfair pumping station in the north-western portion of the city. The tunnel was built for the purpose of furnishing an adequate supply of water to this section of the city and to give an additional supply to the Lake View pumping station, two miles south, which has been in use for many years. The tunnel can carry 350,000,000 gallons of water every twenty-four hours at a velocity of 4 ft. per second.

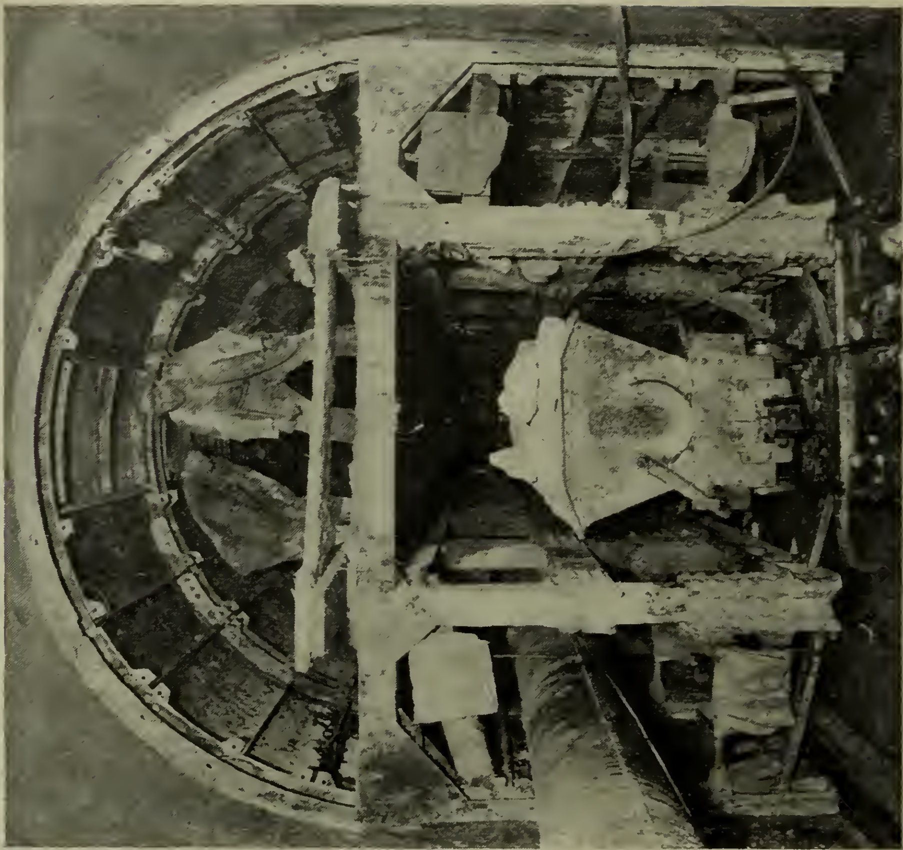
There are many things about the Wilson Avenue Tunnel which make it unique among similar structures in America. In the first place, the difficulties encountered by the engineers were enormous and in many instances unusual, yet the job was completed in record time considering the magnitude of the task. Actual work of digging the tunnel was started in September, 1914, and work was completed by the end of 1918. The work included, besides the digging of the tunnel and giving it a 1-ft. lining of cement, the construction of four 8-ft. shafts on shore. The work was all done by direct labour.

The Department of Public Works is now in a position to supply the old Lake View pumping station with water from the new Wilson Avenue crib, thus getting a purer supply for the former and saving the cost of operation and maintenance of the Lake View crib. This work consisted of driving an 8-ft. tunnel from the Wilson Avenue tunnel, at a point two miles off shore, to a point under the shaft of the Lake View crib, thence upward to within 10½ ft. of the bottom of the shaft and placing a cast steel bulkhead in the vertical section. In order to obtain information regarding the soil to be traversed, diamond-drill borings were made along the route of the tunnel, located about a quarter of a mile apart for the land portion and including six holes in the lake portion. The borings indicated that the best, quickest, and cheapest results would be obtained by driving the tunnel through the solid limestone rock instead of the more or less treacherous soil above, and the plans for the tunnel were so drawn.

The power used at all shafts was 220-volt alternating electric current, with transformers to furnish as much as 800 H.P. at one location. The hoists used were 32 by 24-in. single-drum electric hoists driven by 50-H.P. slip-ring continuous-rating motors. The hoisting speed was set at 200 ft. per minute for a load of 5,000 lbs. Compressed air for operating air drills and placing equipment was supplied by three compressors, each of a capacity of 600 cu. ft. of free air per minute, air being delivered at a normal pressure of 110 lbs. From the compressors the air travelled through a 7-in. header to a receiver 4 ft. in diameter and 12 ft. high, from which a 6-in. pipe line dropped down the shaft and thence branched to 4-in. lines in the short drifts.

The decision was arrived at that the best way to determine the most efficient type and make of drill for any particular rock formation was to equip each shaft with a distinct type of rock drill. Accordingly, the piston type of drill, the water piston type, and the water hammer type were used in the work. The results showed that the most economical type of drill from the standpoint of repair parts was the piston, and the fastest the water hammer drill, although the difference between the drills was not marked in either comparison. It was found, however, that the hammer used less air than the piston drill.

The drainage of the tunnel was done by electrically-driven direct-connected centrifugal pumps. Two sizes of pumps were used: one of 1,000 gallons capacity, and the other of 300 gallons capacity, to work against heads of approximately 150 ft. Care was exercised in the design and installation of the ventilating system



Completed Side-walls and Arch in Foreground.

New Water Tunnel at Chicago.

Placing Steel Forms.

in the tunnel, and a quantity of air much in excess of any heretofore used in similar work was provided. The standard equipment consisted of one centrifugal air compressor of a capacity of 5,000 cu. ft. of air per minute for each drift, at a pressure of 1·5 lbs. where the length of the drift did not exceed 6,000 ft. Where the drifts were longer, two compressors were used in series, giving a capacity of 5,000 cu. ft. at 3 lbs. pressure.

It was decided to employ travelling forms for the tunnel. The controlling feature in the design of these forms was the fact that mining and lining had to be carried on at the same time, so that room had to be provided through the forms for the transportation of soil from the face to the shaft. The forms were especially designed for this purpose, and to suit the clearance required by the dump-cars and locomotives. The forms were of structural shapes and steel plates in 30-ft. sections, mounted on roller-bearing wheels running on 70-lb. rail laid ahead of the work.

In order to obtain information as to which method of tunnelling was best

Section of uncompleted Tunnel, showing Pipe for Delivery of Compressed Air on Left.
New Water Tunnel at Chicago.

Lower Section of Steel Shell of Wilson Avenue Crib showing Buoyancy Chamber.

Steel Shell of Wilson Avenue Crib nearly completed.

NEW WATER TUNNEL AT CHICAGO.

adapted to local conditions, it was decided to try a number of different methods of mining. The standard method of top-heading and bench, operating on the two-shift basis, was used at the Shore Shaft and the Lincoln Avenue and Lawndale Avenue shafts. This method involves the drilling of from 28 to 34 holes in the heading and 8 to 10 holes in the bench. The cut holes were from 12 to 14 ft. deep and some 15-ft. steel was made up in order still further to increase the shot. The bottom heading method with breakdown roof, on the three-shift basis, was used in the single heading from the Mayfair shaft, where the territory was not so built up and where no complaints resulted from the blasting operations carried on day and night. This method involves the drilling of about 23 holes in the bottom heading and 5 holes in the roof heading, the cut holes being from 9 to 10 ft. deep. In general, it was found that the top heading and bench method was the most economical for the rock being mined, operated on the two-shift basis.

The average daily excavation performed on the Wilson Avenue tunnel was about 20 ft., many days running as high as 22 and 23 ft., with a maximum of 26 ft. on one occasion.

After the mining was completed, the excavated rock stored on the surface was crushed and screened, mixed with sand and cement, and brought into the tunnel and placed by hand behind forms of steel or wood. From 30 to 35 ft. per day were lined in this way.

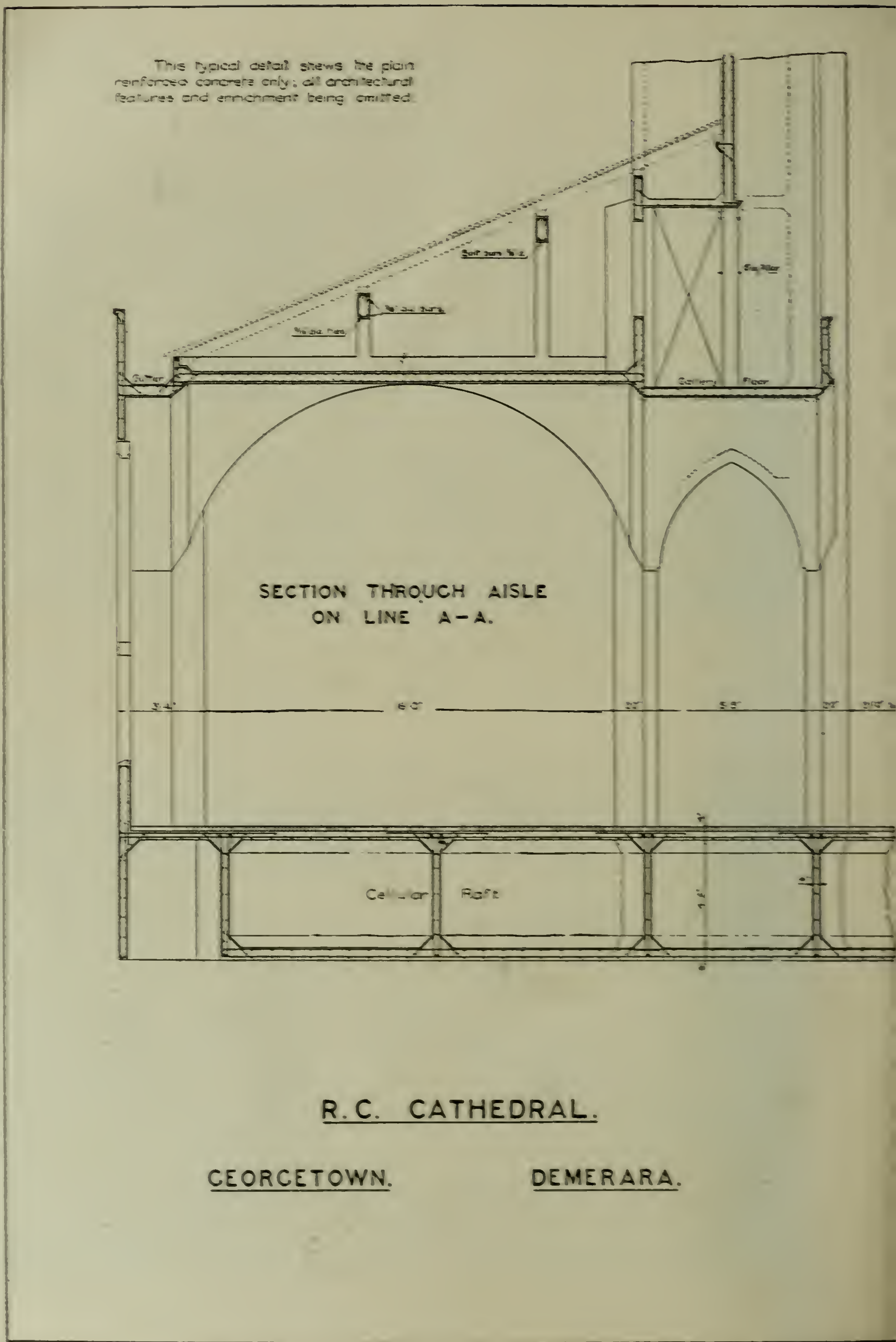
It was found that in the Wilson Avenue tunnel the rock in the mine-run condition made good concrete, and in order to save time and expense a method was devised of lining the tunnel with the mine-run rock in the same drift as the mining was carried on, thus carrying on both operations simultaneously. A screening and loading machine was erected which handled all the rock coming from the heading and deposited the material less than 4 in. in dimension in a hopper over a pneumatic mixer. The pneumatic mixer deposited the concrete through an 8-in. pipe placed behind the steel forms 800 ft. away. The screening machine and the concrete mixer were designed to run on roller-bearing wheels operating on one track and within the clearance of the final tunnel dimensions. The concrete

Wilson Avenue Crib showing Masonry on Steel Shell.
New Water Tunnel at Chicago.

forms were made of steel operating on a traveller on roller-bearing wheels which could be easily moved. By means of this system, approximately 60 ft. of forms were lined in two shifts with 60 ft. of concrete forms, the concrete only setting about sixteen hours before the forms were removed. Between 20 and 22 ft. a day was mined and approximately 60 ft. of tunnel lined with the excavated material on each working day in each drift.

In advance of the steel forms, guide walls were constructed by hand concreting. These walls were made of wooden forms set to the true line and grade from the centre-line and grade plugs, and guided the steel forms so that the finished lining was true to line and grade.

The crib constructed three miles out in the lake is of a different design from any previously constructed by the city of Chicago. The plans for the Wilson Avenue crib comprised two concentric shells, the outer shell being $\frac{3}{8}$ in. thick and 90 ft. in diameter. These two shells are held together by intermediate bracings and the intake ports. By correct calculations with the ports, bulkhead, and the intermediate flotation chambers attached to the bracing, a sufficient buoyancy was obtained to float the steel shells in the same way as a vessel. The steel shells had cutting edges on the bottom in order that the crib might seal itself into the bed of the lake, thus permitting the pumping out of the intermediate wall when the work of sinking the shaft was started.



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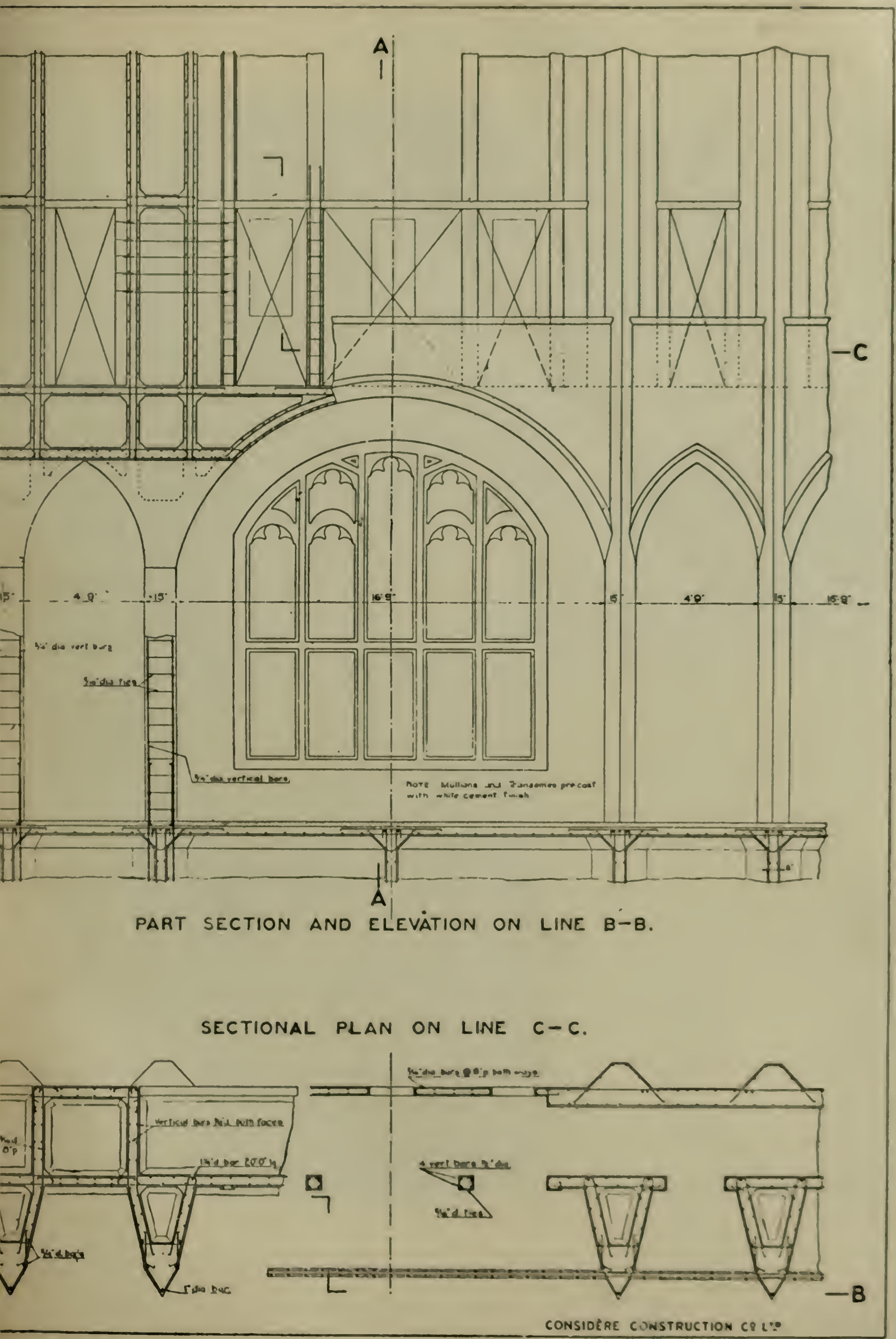
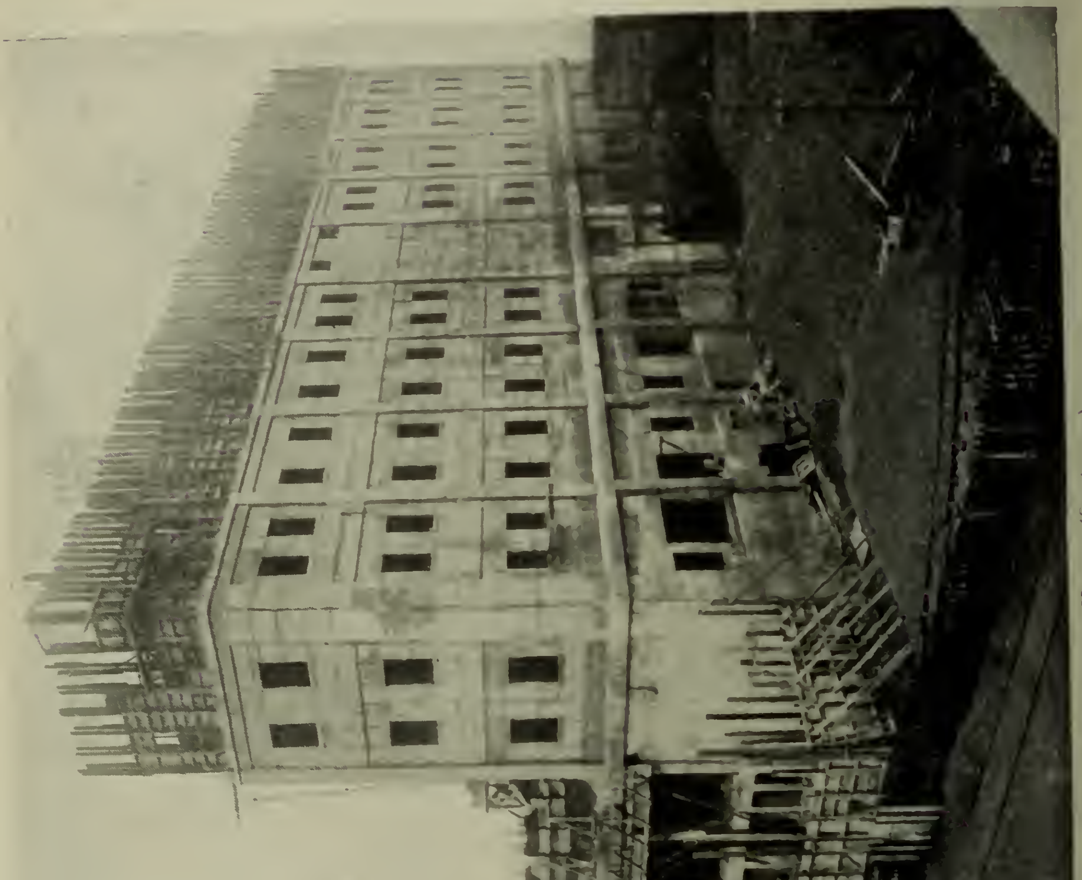


ARA. (*See p.* 431.)

[*Mr. Leonard Stokes, PP.R.I.B.A., Architect.*



MOVING FORMS AT THE KING GEORGE DOCK, HULL. (See p. 459.)

[Side view of bins, showing the moving forms. One concreting wagon is seen at work, and the jacking crew may be discerned in the background.]

MOVING FORMS.

At a meeting of the Concrete Institute on April 27, Mr. E. F. Sargeant, A.M.Inst.C.E., M.Inst.M.E., read a paper entitled "Moving Forms." The President (Mr. E. Fiander Etchells) occupied the Chair.

At the outset, the speaker pointed out that by moving forms he intended to convey the system of shuttering which moved upwards gradually and continuously as the work proceeded, which was a system of shuttering surrounding vertical work suspended in such a way that it could be gradually drawn upwards as the concrete set, while fresh concrete was poured in at the top making the work continuous.

In principle, the idea of a moving form was very simple and very attractive. In the case of a cylindrical chimney shaft, a ring of shuttering was constructed on the foundations to form the inner and the outer face of the chimney, consisting of battens, say, 2 in. thick by 4 ft. long, with horizontal bracings inside and out. The two rings were joined together by steel inverted U-shape frames. Through the cross-bar of the inverted U-shape frames passed a powerful screw, the lower end of which bore upon a length of steel tube resting on the foundations between the two rings of shutters. Concrete of fairly stiff consistency at first, but afterwards of the consistency of ordinary spouted concrete, was poured between the shutters. When the concrete was about 3 ft. 6 in. high the screws in the frame were turned down, and, pressing on the tubes, raised the frames and with them the rings of shuttering to which they were bolted. As the shutters gradually rose more concrete was poured in at the top of the forms, and the operation of raising them was sufficiently slow for the concrete to set before it was exposed at the bottom of the shutters. However lofty the work might be the shuttering was never disturbed after it was once fixed, but was gradually travelled upwards as the concrete set. Where the shutters were 4 ft. deep an average rate of progression of 2 ft. per day could be obtained, which gave nearly two days from the time the concrete was deposited at the top of the shutters to the time it was uncovered at the bottom edge of the shutters, when it would be found sufficiently hard to stand by itself and to bear the load.

The tubes on which the jack screws bore remained embedded in the concrete, and as the jack screw was of limited length (say 2 ft.), fresh lengths of tubes had to be inserted directly the jack screw had been screwed down to its full length so that the latter could take a fresh bearing. That was accomplished by using two tubes to each screw placed one inside the other and being a fairly good sliding fit. The bottom tube, which rested on the foundations, was, say, 5 ft. long, and inside that was placed another tube, fitting it closely, 4 ft. 6 in. long. When the jack screws were screwed down as far as they would go every alternate jack screw was screwed up to its full height, and an inner tube 1 ft. long was slipped inside the long tube resting on top of the inner tube which was already there; then an outer tube, also 1 ft. long, was slipped over the projecting end of the inner tube and rested on the end of the outer tube, thus adding 1 ft. to its length, so that the jack screw could now take a fresh bearing 1 ft. higher up than when it left off. By that means the jack screw was supported as the work proceeded on a steel tube built up out of a large number of short lengths which butted together and were kept in position by an inner series of short tubes breaking joint with the former. The tubes formed no part of the permanent reinforcement.

The operation when once started should, if possible, be continuous; that is, when once the jacking-up of the forms had commenced it should be continued slowly at the rate of about 2 in. per hour until the top of the chimney was reached, fresh concrete being continually deposited at the same rate. Should that not be done there was great danger of the concrete setting and adhering to the inside of the shutters, so that when jacking was resumed the concrete was lifted upwards bodily with the shutters. When that occurred the adhering concrete had to be broken down with crow-bars and fresh concrete poured in, which was troublesome and expensive, but otherwise caused no material damage to the work.

The advantages of that system of construction were that no scaffolding was required, the whole weight resting on the jack screws, and no expense was incurred with the shuttering after it was once in place other than that of screwing down the jack screws three or four times an hour so as to give an average rate of about 2 in. per hour. The disadvantages were those of continuous working, involving night shifts, and the cost of jack screws and the tubes on which they rested. Continuous working was not altogether a disadvantage in concrete, since it did away with that weak spot in its construction, namely, the joint between one day's work and the next, while the expense of the jack screws and frames was, of course, greatly reduced if a number of jobs had to be undertaken.

In using moving forms there were two essentials to be observed, (1) the concrete must be deposited evenly over the whole area, and (2) the forms must be kept constantly moving upwards so as to prevent the concrete setting and adhering to them. It is fairly easy to attain both these objects in the construction of a single bin or tower of small dimensions, but owing to the fact that it was not possible to progress at the rate of more than 2 ft. in the twenty-four hours the quantity of concrete required per day was so small that it hardly paid to use moving forms ; when a large number of bins had to be constructed in a single group, however, the case was very different.

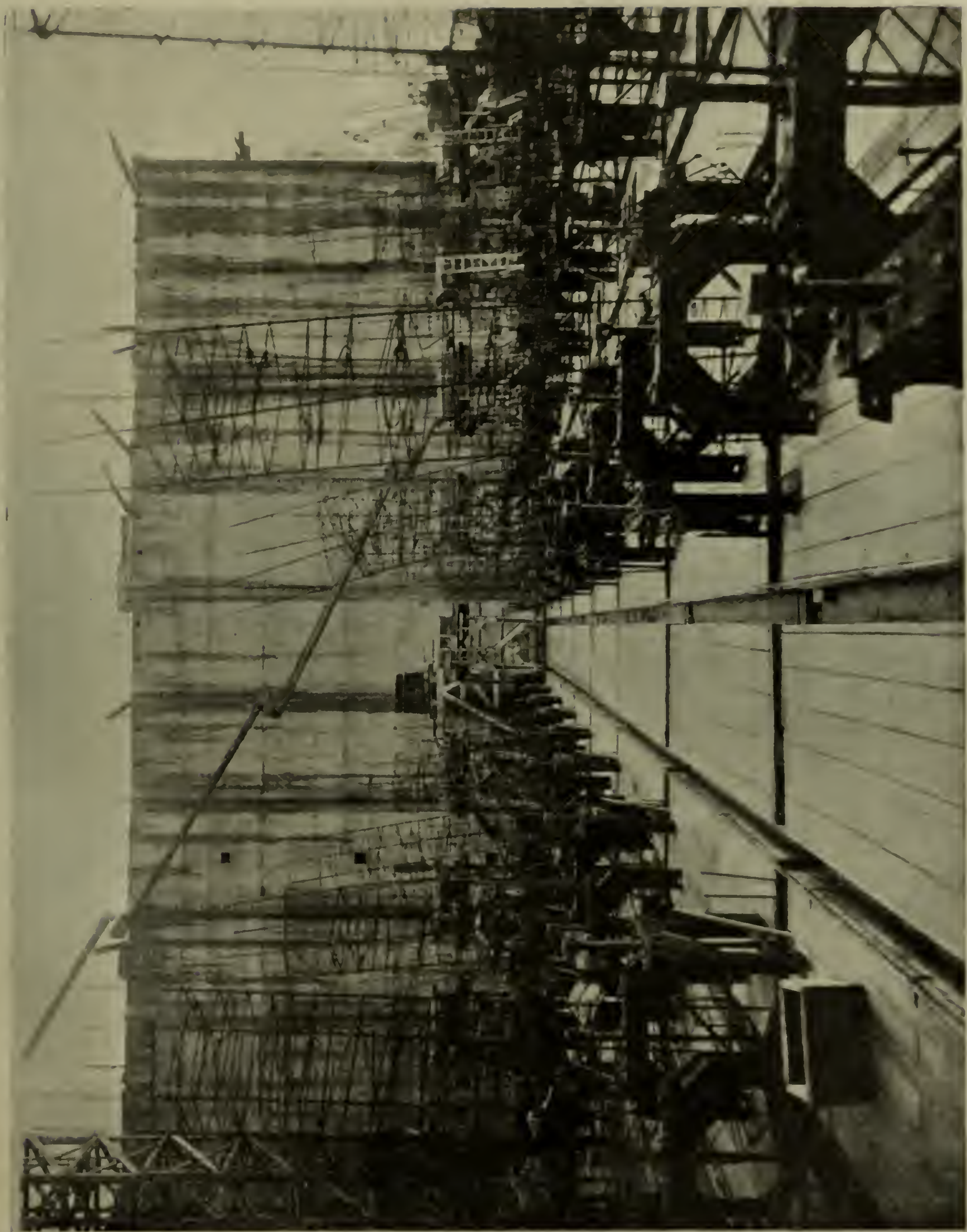
The lecturer then gave an account of the construction, a few years ago, of a large grain silo at the King George Dock, Hull, consisting of two groups of bins, each group containing 144 bins, of which he was in charge. It was decided to construct these silos with moving forms, although they had not been previously used in England.

Each block of bins was 216 ft. 6 in. long by 96 ft. 6 in. wide, and consisted of eight rows of eighteen bins in each row, the bins terminating below in hopper-mouths supported on beams and columns. The hopper-mouths and beams and columns were shuttered and cast in the ordinary way, and when the whole of that work was finished the shuttering for the moving forms was assembled in place.

The yoke, or inverted U-frame, consisted of two vertical angle-irons 6 ft. long connected at the top by a cross member with gusset pieces. Two angle-iron cleats were bolted to each of the vertical angle-irons, one at the bottom and one 2 ft. higher up, to which were secured horizontal walings which supported the shuttering. To the top cross member was bolted a cast-iron nut through which a 2-in. screw passed, having a pitch of three to the inch ; the screw terminated in a spigot which went inside the steel tubes. The whole of the shuttering hung from the yokes, which in turn were carried on the steel tubes. At each of the corners of each bin was a column 2 ft. square, placed diagonally to the walls of the bin so that the sides of the columns formed truncated corners to the bins ; the columns carried vertical reinforcement, while in the bin walls was horizontal reinforcement only, except in the exterior walls. Each column was surrounded by four jacks, there being 612 jacks over the whole area. A decking formed at the top of the shuttering gave a working platform over the whole area.

In designing the concrete lay-out for the job the problem had first to be considered how to distribute the concrete uniformly into the longitudinal and cross walls over the area of 216 ft. by 96 ft. and, second, how to raise the platform, measuring 216 ft. by 96 ft., uniformly and gradually and at the same time keep it level throughout. It further had to be considered how the system of jacks and shuttering was to be removed when the bins were at their full height, and how the shuttering for the beams and floor slabs was to be got in place so as to enable the top floor to be cast.

The concreting system adopted for the rest of the job consisted of a 1-yd. mixer which delivered into an elevator bucket at the bottom of a tower about 150 ft. high placed between the two groups of bins, and it was suggested to take the concrete from this tower by chutes suspended to cables and to distribute it from auxiliary swinging chutes direct into the walls. It was also suggested to form the top floor of pre-cast slabs resting on concrete beams, which would be cast in suitable boxes after the moving forms had been taken down. The total quantity of concrete to form the walls and columns of this group was nearly 90 cu. yds. per foot of height, and as it was desired to progress at the rate of nearly 2 ft. per day, it meant distributing 180 cu. yds. of concrete per day evenly over 7-in. walls contained in an area of 216 ft. by 96 ft. ;



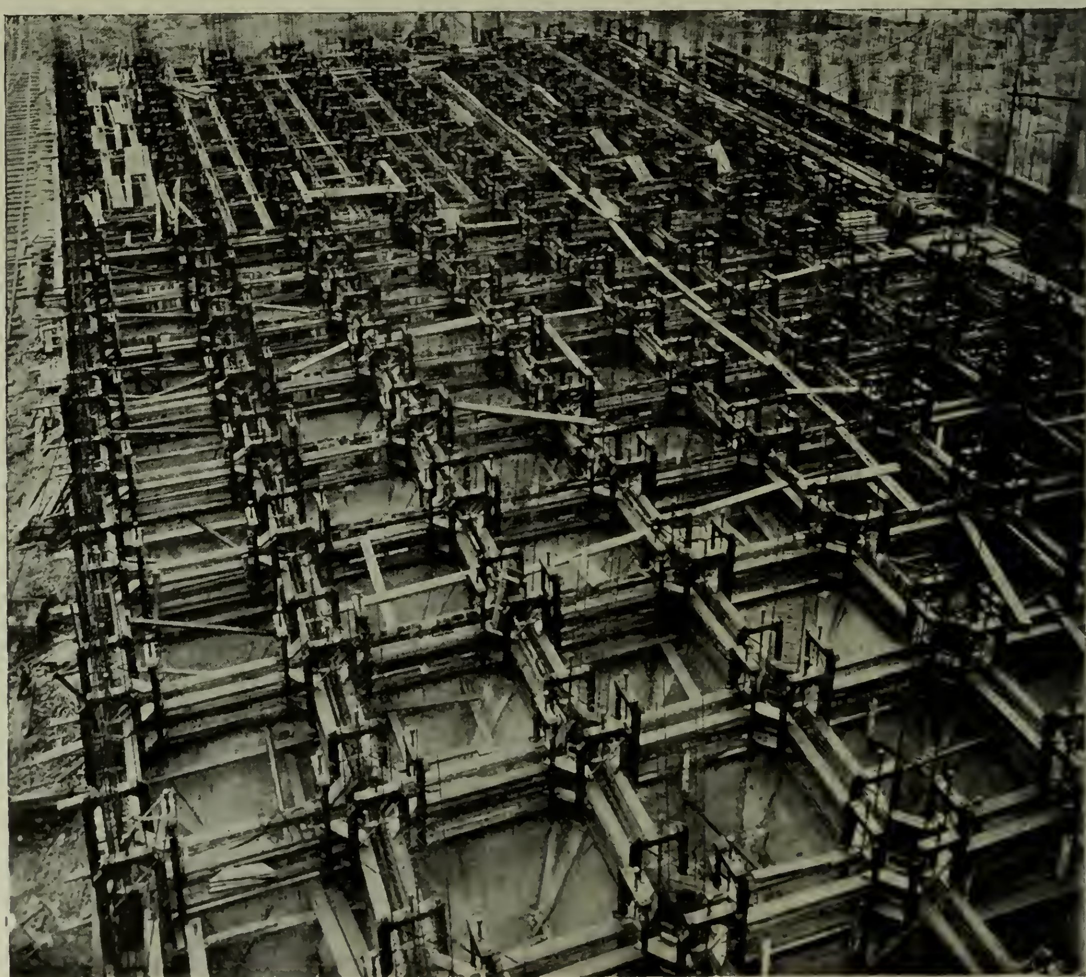
[Showing the jacks and decking complete. The eight concreting wagons, the transporter wagon, and the chute from the concrete tower are shown in the background.]

MOVING FORMS AT THE KING GEORGE DOCK, HULL.

it was quite apparent, therefore, that unless a systematic method of depositing the concrete were adopted, uniformity of placing over the area would not be obtained. Further it was considered extremely hazardous to attempt to shutter the beams of the top floor after the beams of the moving forms were taken down.

Instead, therefore, of forming a decking over the moving form, the decking was arranged from the start to form the shuttering for the top floor, which was carried across each bin by two beams placed about 4 ft. apart.

The system of concrete distribution was as follows: The main chute from the concrete tower discharged at one end of the block of bins into a jubilee wagon holding 1 cu. yd. of concrete carried on a lofty carriage about 10 ft. high. The wagon ran on rails laid on the decking, and could be pushed across the width of the block as required. The actual concreting wagons ran on rails at right-angles to the first set, and were laid down the whole length of the block. There were eight concreting wagons running on eight pairs of rails, one for each row of bins. The concrete mixer was of 1 cu. yd. capacity, as was also the bucket elevator. When the transporter wagon was in place under the concrete chute the man at the winding engine was signalled to send up a batch of concrete, which was automatically dumped into the hopper at the top of the tower. When the valve controlling the hopper was opened, the concrete ran down the chute and filled the transporter wagon. It took twenty seconds from the time the valve was released to the time



Moving Forms at the King George Dock, Hull.

[Showing jacks assembled at each corner of each bin, with two rows of walings around each wall. In the background the vertical shuttering and the beam boxes to form the concrete beams of the top floor are seen in place. The decking is not yet laid. The hopper bottoms are shown. All the plant in this view ascends as the concreting proceeds.]

the transporter wagon was full. The transporter wagon was then pushed to where one of the concreting wagons was waiting for it, and was discharged into the concreting wagon by tipping the box at the top. The concreting wagon consisted of a wooden box, 6 ft. square by about 2 ft. deep, carried on a lofty truck at about 8 ft. from the ground. A platform surrounded each box, on which stood a couple of men who controlled the flow of the concrete.

The concrete flowed from the concrete wagons through three gates or valves, one on each side of the wagon and one in the front. A swinging chute into which the concrete was discharged was attached to each side of the wagon, and when the chute was at right-angles to the wagon its end was vertically over a longitudinal wall. It terminated about 4 ft. above the decking, and from its outer end hung a sheet-iron pipe which came down to the level of the decking. The swinging chutes were necessary in order to avoid the vertical reinforcement of the columns. From the front valve of the wagon a fixed chute was taken which divided into two chutes, each of which terminated a little above the decking, and from these chutes the cross walls were filled. A load of concrete was distributed over a length of two to three bins, raising the wall 3 or 4 in. The wagon was discharged in about six minutes. The concrete was poured continuously and evenly over the whole area, the concrete mixer sending up fairly regularly 1 cu. yd. of concrete every three minutes, or 20 cu. yds. per hour.

The whole staff, including wheeling cement, hoist man, mixer man, and the crews of the wagons never exceeded thirty-five men, or, say, thirty-five hours' labour per 20 cu. yds. of concrete, or about 1¾ hours per cu. yd.

There were nineteen rows of jacks across the building with thirty-four jacks in each row, less a certain number in the two end rows, and the problem was to work these jacks regularly throughout the day so long as concreting was proceeding so as to bring up the whole decking at a uniform rate and without allowing any part to stand long enough for the concrete to adhere to the shuttering. This was accomplished by a gang of thirty-four boys under the charge of one man; each boy carried a tommy bar about 2 ft. long and the jack screws were provided with two tommy holes at the top end. The boys were lined up across the decking, one boy to each jack, and at the sound of a whistle each boy would give a couple of half-turns to the jack screw, thus raising the jack about ⅛ in. Thus the gang would move from end to end of the building, completing the journey in about ten minutes. The jack screw had a thread 1 ft. 9 in. long, and the tubes on which the jack screws rested were in 12-in. lengths, having an inner and an outer tube breaking joint so that when threaded together the tubes made a fairly rigid column. When a jack screw had been turned down 12 in. the tube gang following up screwed it up again, and inserted a fresh inner and outer tube, leaving the screw bearing on the new length in readiness for the next turn. The total gang attending to these jacks and tubes was forty, and they raised the whole shuttering 1 yd. in eighteen hours' work, or 720 hours total. The total shuttering 1 yd. height in the group of 144 bins amounted to 2,400 sq. yds., so the work done was equivalent to the striking and re-setting of 2,400 yds. of shuttering per yd. of height at a labour cost of 720 hours, or roughly 3 sq. yds. of shuttering per hour of boy labour, which at the rates then prevailing amounted to 2*d.* per sq. yd. To that must be added capital cost of the jacks and timber and of assembling them at the beginning of the job, but not the cost of dismantling the moving forms at the top of the building, which was charged to the cost of shuttering the top floor, for which purpose the decking had been specially constructed. The total capital cost, including assembling, erecting, and timber, amounted to about 1*s.* 7*d.* per sq. yd. of bin wall surface, which added to the cost of operating made a total of 1*s.* 9*d.* per yd. super of wall surface, leaving the jacks and the timber, all of which appeared to be good enough for another job of the same magnitude, as a credit for which no value had been taken.

Many difficulties were experienced in this work owing to the war-time conditions prevailing, but the lay-out worked satisfactorily from start to finish.

In concrete bins no difficulties occurred from the introduction of windows, door openings, etc., but moving forms could be used for ordinary domestic buildings by careful adaptation of the details.

DISCUSSION.

Mr. Harrington Hudson asked whether the lecturer had thought of spouting the concrete direct into the forms instead of using the eight wagons, thus avoiding the transporting of the concrete after it had left the spout. For circular silos in Lahore some time ago he had used a steel pipe in the centre of the silo, and a circular shuttering made of steel plates on a timber frame on the inside of the silo. The outside consisted of steel plates, with bolts clamped through on to the inner shuttering. The steel plates were 5 ft. high on a timber frame, and could be hoisted to the top of the steel centre by a block and pulley. About 4 ft. of concrete was placed at a time. When this was placed, both clamps through the concrete were taken out and the complete ring of shuttering raised.

In reply, the **Lecturer** said the cost of moving spouting from one fixed spot to another was fairly high; to avoid this many spouting plants had a jib supported from the centre, working over a large radius, while other spouting plants had a second jib attached to that. By working over a big radius with the first jib, and a second radius from the end of that first jib, one could practically cover any area of concrete. On the work he had described he found an extensive spouting plant; but labour cost made it impossible to use spouting throughout the whole of the area. By having eight wagons travelling on parallel tracks over the area he could ensure that no part of the concrete was more than a few inches higher than any other part. With the apparatus used, he got the lowest labour cost per cubic yard. The jacks bore upon tubes about 1¼ in. in diameter, and the tubes were erected upon the solid concrete from which the work started, the bottom tube being 5 ft. long. The tubes were supported on the concrete. The concrete was deposited at the rate of 2 in. an hour, and the jacks were raised at the same rate, uniformly throughout. When the jacks had gone up 4 ft., the concrete came out at the bottom of the jacks and set hard. There was only an unsupported length of 18 in. or 2 ft. of tubing. The weight of the concrete wagons gave a very heavy pressure on the tubes; sometimes they buckled and had to be replaced, but no practical difficulty was raised by that. The work had progressed at the rate of 2 in. an hour, making about 2 ft. during the twenty-four hours.

FLOATING DOCKS.

At a meeting of the Concrete Institute, held recently, Mr. S. F. Staples, M. Inst. C.E., M.I.N.A., read a paper entitled "Floating Docks." After giving an interesting account of the development of these structures, and describing the principal types now in use, he said the more important stresses which came upon the material forming the hull of a floating dock were: (1) Water pressure; (2) transverse bending moment due to the pressure of the keel of the ship on the keel-blocks; (3) longitudinal bending moment due to the bearing length of the ship not extending as a rule over the full length of the pontoon.

Taking the condition of affairs when the dock was floating with its deck just above the water and with a ship resting on the keel-blocks, the lifting power was the pressure of the water exerted evenly all over the bottom plating. Part of that pressure went to support the weight of the dock, and the remainder had to neutralise the weight of the ship applied along the line of the keel-blocks. The evenly spread water-pressure over the whole bottom, therefore, had to be concentrated into a single line running along the centre of the dock. The load on the skin plating was in the first instance taken from the skin to the frames, and from the frames to the transverse bulkheads which ran right across the dock. Those transverse bulkheads took the load off the frames, and transmitted it to the central bulkhead upon which the keel-blocks rested.

The effect of the loads from the frames coming upon the transverse girders was to set up in them bending moments, the bottom skin plating forming the tension member and the pontoon deck the compression member.

It being always impracticable to pump water from the dock exactly under the limits of bearing length of the keel of the ship, it followed that the water pressure on the skin of the dock beyond the ship bearing blocks had no weight to oppose it directly. Some portion of it found its way to the loaded portion of the central longitudinal bulkhead along the bulkhead itself; but the major portion, when the load was considerable, had to travel outwards to the walls, and was transmitted by them to the ends of the transverse bulkheads, and so to the loaded portion of the central bulkhead.

When the dock, instead of supporting a ship above the surface, was lowered, some of the stresses in the skin plating would be reversed owing to the weight of the side walls being considerably greater than their net displacement, the bottom plating, treated as the lower flange of the transverse girders, being then in compression, and the pontoon deck in tension.

After referring to the difficulties of designing floating docks in reinforced concrete owing to the weight of the material in the skin plating, he said there was, however, another form of floating dock in which it might be found advantageous to make use of reinforced concrete. If a reinforced concrete floating dock were designed with the longitudinal and transverse girders of normal strength, but with the skin plating only just strong enough to enable it to float, and one end were closed in a manner similar to that in which the side-walls were constructed, that would form a complete lining to a graving dock. Where the ground was bad, the whole of the excavation could be done in the wet, and the floating lining towed into place and lowered so that it rested lightly on the bottom. Weak concrete could be forced down pipes led through the pontoon deck and bottom so as to ensure a firm and even seating for the floating dock, which would then be filled up solid with weak concrete. The deformation of the walls of a dock thus constructed should be very small, so that the sill and side facings for the caisson to bear against would be built before the floating dock was lowered, and the whole of the cofferdam and pumping during construction would be done away with. He was connected with a somewhat similar scheme some years ago in connection with the new harbour of Kobe. There the quay walls were constructed of hollow blocks of reinforced concrete about 120 ft. long, varying from 35 ft. to 41 ft. high, and having an average breadth of about 30 ft., the finished weight being in the neighbourhood of 6,000 tons. They were built on a grid erected on the edge of the sea, and the blocks were picked off the grids by a depositing dock and subsequently lowered into deep water by the dock. Before filling they weighed about 2,000 tons, so that they could be then towed to their destination and sunk by the admission of water. That proved a very successful method of construction, and with modifications had been followed in other harbours.

DISCUSSION.

In the ensuing discussion the **President** said with regard to the amount of steel in concrete docks, the members of the Institute never feared facts. As a scientific body they had no part with those who made extraordinary claims for concrete, although it was admittedly a good material. He had known cases where it had been claimed that if concrete were used 60 per cent. would be saved in the cost of the structure. Such claims were not put forward by members of the Institute.

Mr. H. J. Deane said there was a very large amount of discussion as to whether floating docks or graving docks were the right thing. He did not take any hard and fast view on the subject, because each particular type had its own particular uses. The small reinforced concrete dock had its own particular uses during the war, and reinforced concrete floating docks of large capacity were at present hardly possible. Therefore, they must consider the circumstances under which floating docks were to be used before deciding upon their construction. A great argument in favour of floating docks was that they could be transported, and from the point of view of the Admiralty they were most excellent tools. If they examined the contours of the bottom, the width, etc., he believed they would come to the conclusion that there were very few spots on the Thames where they could safely place a dock of this description without having to undertake a very large amount of dredging, and possibly a very large amount of excavation of the foreshores. With regard to wet docks, it was impossible to conceive the construction of a floating dock inside a wet dock, because it would not only mean the excavation which was necessary for the construction of the wet dock, but also the quay walls which would be necessary to keep up the sides, and so on. The wet docks therefore must have, for the sake of convenience, their own graving docks within their own boundaries, so that ships could go into the docks to receive treatment. Again, with regard to floating docks, there was the question of the influence of the tides; it was obvious that big docks must run a great deal more risk in a seaway than a graving dock. Therefore, he imagined they always had to be placed in a position which was more or less sheltered. Nevertheless, he had a great admiration for them, and considered them to be the right things in the right places, provided they could get the depth of water without very much dredging, the necessary width, etc.

Dr. Salmon said he was glad Mr. Staples had emphasised the value of the "off-shore" dock, because it was not generally realised what a good thing it was. For small ships he believed it was the best.

Mr. White said in some docks there was an air space running through the centre of the pontoon, and if there were an air space in the pontoon why should they not have water in the side walls, so that when they wanted to lift the dock they could pump the water out of the pontoon, leaving the water in the side walls, then open valves in the side walls and let the water run out by gravity? That would save pumping to a certain extent.

Mr. Sinclair, speaking of side shores in a dock, said he took it that those shores were limited, inasmuch as the range was limited. How would they get over the difficulty if there were a ship in the dry dock so narrow that the side shores would not reach it? He presumed portable shores would have to be used. With regard to sectional self-docking docks, he asked how the joints between the sections were made, because there were no doubt heavy stresses set up in the side walls of the dock, especially in a very heavy dock where the stresses were unevenly distributed over the whole. As to the one-sided dock used in connection with grid-irons, he took it that their action was limited to particular types of vessel. It would be very convenient to pick up a flat-bottomed ship and put it on the grid, because it would rest on the flat bottom. If they had a ship which ran away quickly to the keel it would be more difficult, and he would like to know how to get over that difficulty.

Mr. Marshall, referring to wind pressures, said about fifteen years ago he had seen a floating dock at Singapore, which had been towed across the Atlantic, through the Mediterranean, through the Suez Canal, and across the Indian Ocean.

Mr. Staples, replying to the discussion, said he agreed that there was plenty of room for both floating and graving docks; neither was perfect for any and every situation. As to the question of the giving way of the side shores letting the ship over, in the ordinary way a floating dock did not have side shores. It had bilge shores, which were solid blocks of timber, with a steel base, so that there was no risk of a vessel falling from the bilge shores any more than from the keel blocks; accordingly, an accident of that sort could not happen. There were only two or three side shores on either side, and these were merely used for the purpose of centering the ship. Therefore, from that point of view they were much safer with a floating dock than with a graving dock. If they had a ship with a considerable list it would be difficult to deal with it in a graving dock, but with a floating dock one side could be lowered so that the dock would be at such an angle as would correspond to the list of the ship. With regard to mooring floating docks, he mentioned a number of cases in which they had been moored in the open sea, including a dock at Valparaiso, which was moored in the open Pacific. When the dock was sunk there was very little for the waves to get hold of; there was a big, flat pontoon, which had to be dragged up and down, and there was only the displacement of the side walls to drag that up and down. Consequently, there was a firm base for the ship to rest on, and there was no chance of the dock and the ship bumping. With regard to air spaces in the pontoons, a great many docks were made with air spaces. Also, they were made so that the water could be run out of the walls by gravity instead of pumping, but when they counterbalanced the weight of the dock it meant that they had so much less weight to sink, and it might take quite a long time to sink the last 4 or 5 ft. It meant extra watertight decks and extra ballast, and would add considerably to first cost. As to the length of side shores, they were made as long as they could be made, consistent with strength. From time to time, where a dock had to deal with a large variety of ships, they made a hinged nose on the side shores. They put a hole through the side shore a couple of feet from the end, and on either side of that a cambered channel, and clamped another piece of timber on, say, 10 ft. long. That could be hinged up in the air when dealing with a wide ship, or lowered for a narrow ship. That had proved very satisfactory.

The vote of thanks to the lecturer (proposed by Mr. Deane and seconded by Mr. W. J. H. Leverton) was carried with acclamation.

Concrete and Fire Prevention.

THE series of "Red Books" of the British Fire Prevention Committee dealing with the tests on the fire-resistance of plain and reinforced concrete carried out with assistance from the Department of Scientific and Industrial Research is now complete. The series, numbering 31 volumes, has been published by H.M. Stationery Office, the total cost of the individual volumes as published being £4 7s. 6d. To bring the results of the tests as a whole within the reach of all interested complete sets (31 volumes) are being placed on sale at the price of £2 (by post £2 1s. 6d.). A complete list of the volumes may be obtained from H.M. Stationery Office.

RECTANGULAR SLABS: VARYING AMOUNTS OF FIXATION AT THE SIDES.

By Wm. HUGHES.

In dealing with reinforced concrete slabs one frequently comes across the case of a slab with different amounts of fixation at the ends of the two axes. In this case it will be apparent that the Grashof-Rankine formula for slabs with the same degree of fixation at the boundaries cannot be accurate, and, in fact, it is likely in certain cases to be about 24 per cent. in error.

I propose to extend the Grashof-Rankine theory to deal with this case. The following assumptions will be made :—

(1) That the moment of inertia is equal in all directions ; in slabs which are even approximately square this will be sufficiently true for practical purposes.

(2) That for all practical purposes the bending moments in continuous spans will be either $\frac{wl^2}{12}$ or $\frac{wl^2}{10}$ and in freely supported spans $\frac{wl^2}{8}$.

Three cases will be taken, which will cover all ordinary arrangements of spans, viz. :—

(1) $\frac{w_1 l_1^2}{12}$ one way and $\frac{w_2 l_2^2}{8}$ the other.

(2) $\frac{w_1 l_1^2}{10}$,, ,, ,, ,, ,,

(3) $\frac{w_1 l_1^2}{12}$,, ,, $\frac{w_2 l_2^2}{10}$,, ,,

These three cases correspond to :—

(1) A long slab supported at each side and with secondary beams at intervals in its length.

(2) The end bay of such a system.

(3) A bay which is an end bay in one direction but an intermediate bay in the other.

Any arrangement of spans in which the moments on the axes are the same function of wl^2 will be treated by the ordinary Grashof-Rankine rule and need not be noticed here.

Case 1.—Let W be the total unit load, l_1 the length of the partially-fixed span and l_2 the length of the free span, w_1 and w_2 being the respective portions of the load taken in each direction. Then, if the moment $\frac{w_1 l_1^2}{12}$ is obtained by equal amounts of fixation at each end, a very reasonable assumption, the *def.* Δ on this axis is

$$\Delta = 3/384 \frac{w_1 l_1^4}{EI},$$

and in the case of the axis of the freely supported span

$$\Delta = 5/384 \frac{w_2 l_2^4}{EI}$$

equating deflections :—

$$3/384\frac{w_1 l_1^4}{EI} = \frac{5}{384}\ \frac{w_2 l_2^4}{EI}$$

whence

$$\left(\frac{l_2}{l_1}\right)^4 = \cdot 6\frac{w_1}{w_2}$$

but

$$w_1 + w_2 = W \text{ and } W_1 = \frac{w_2}{\cdot 6}\left(\frac{l_2}{l_1}\right)^4$$

whence

$$w_2\left(1 + \frac{l_2^4}{\cdot 6 l_1^4}\right) = W$$

and

$$w_2 = \frac{\cdot 6 l_1^4}{\cdot 6 l_1^4 + l_2^4}\cdot W = \frac{\cdot 6}{\cdot 6 + \left(\frac{l_2}{l_1}\right)^4}\cdot W$$

Similarly

$$w_1 = \frac{1}{1 + \cdot 6\left(\frac{l_1}{l_2}\right)^4}\cdot W$$

CASE 2.—With notation as for Case 1, it will be found that an end span with a fixing moment of $\frac{w_1 l_1^2}{19}$ at one end and free at the other will give a maximum span moment of $\frac{w_1 l_1^2}{10}$ and the deflection Δ will be $\frac{3\cdot 76}{384}\cdot\frac{w_1 l_1^4}{EI}$ equating deflections we get :—

$$\frac{3\cdot 76}{384}\cdot\frac{w_1 l_1^4}{EI} = \frac{5}{384}\ \frac{w_2 l_2^4}{EI}$$

whence proceeding as in Case 1 we get

$$w_2 = \frac{\cdot 752}{\cdot 752 + \left(\frac{l_2}{l_1}\right)^4}\cdot W$$

and

$$w_1 = \frac{1}{1 + \cdot 752\left(\frac{l_1}{l_2}\right)^4}\cdot W$$

CASE 3.—With notation as for preceding cases and equating deflections we get :—

$$3/384\cdot\frac{w_1 l_1^4}{EI} = \frac{3\cdot 76}{384}\cdot\frac{w_2 l_2^4}{EI}$$

whence, as before, we get :—

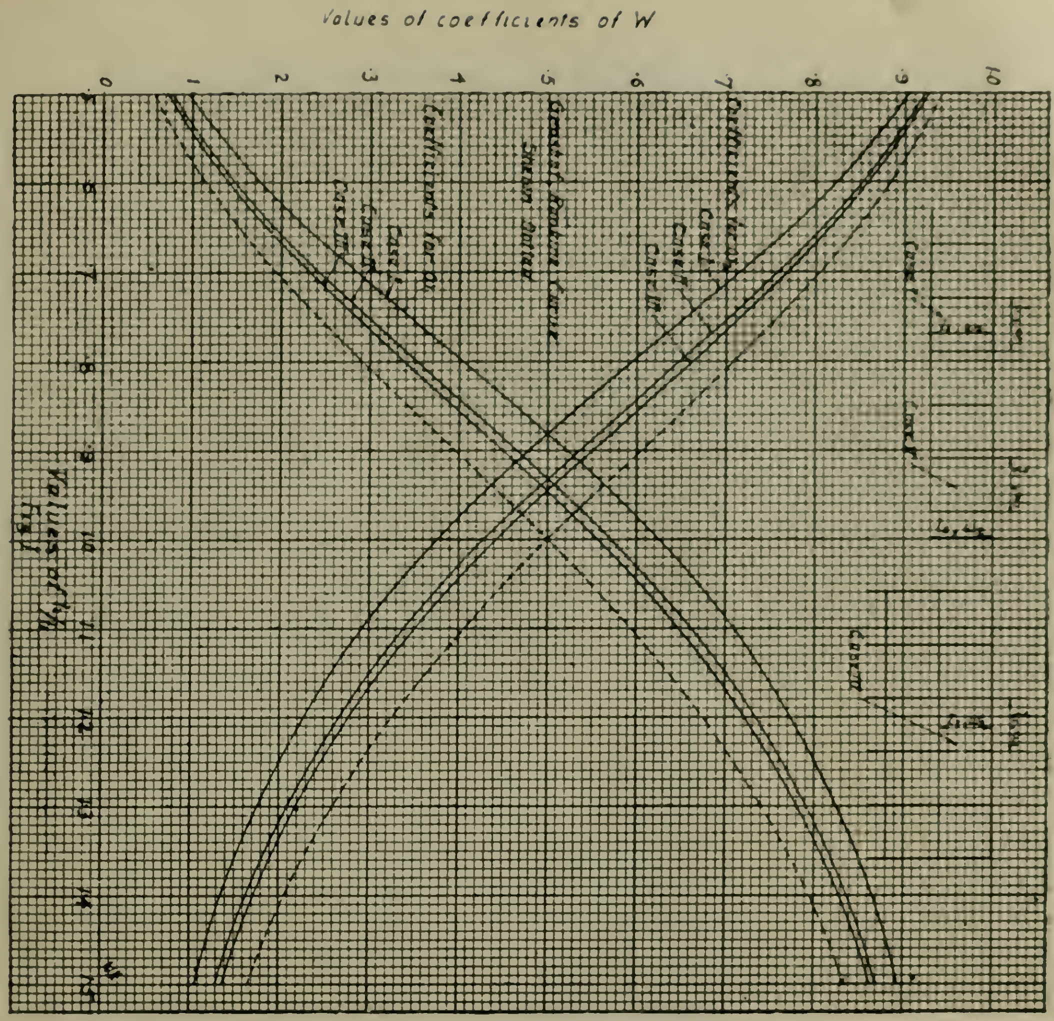
$$w_2 = \frac{\cdot 798}{\cdot 798 + \left(\frac{l_2}{l_1}\right)^4}\cdot W$$

and

$$w_1 = \frac{1}{1 + \cdot 798\left(\frac{l_1}{l_2}\right)^4}\cdot W$$

In all cases w_1 and l_1 have been taken to refer to the span with the greater fixation and w_2 and l_2 to the span with the lesser degree of fixation. The graphs give values of the coefficients of W for the various cases and are plotted to a base of l_2/l_1, e.g., ratio of span of lesser fixation to that of greater fixation. The Grashof-Rankine graph has been plotted for comparison, from which the serious divergence for values of l_2/l_1 of from ·8 to 1·3 will be noticed. The ratio has been extended below unity, because it is not a ratio of length to breadth but of span of lesser to span of greater fixation, and the range ·5 to 1·5 covers most practical cases.

Rectangular slabs fail on diagonal axes, but such failure would be expected from the above theory, and the stresses could be calculated by resolving the axial tensions, in the neighbourhood of the corner, normal to the bisector of the angle.



While it is not pretended that the above is a complete analysis of the subject it is probably sufficiently near the truth to serve its purpose, viz., the apportioning of the steel in slabs which occur in actual practice.

Referring to the second assumption, it has been the experience of the writer that the moments given, which are "Worst cases" given in the L.C.C. Regulations for Reinforced Concrete, are very approximately those found in practice, and that the variation from them is too slight to be of any great practical importance having regard to the confusion of opinion on fundamental matters of the theory of reinforced concrete.

CONCRETE RAILWAY WAGONS.

The first 15-ton railway wagon built for the Minden Concrete Works has been submitted to the German Official Railway Testing Station for examination. It has proved remarkably resistant to shocks and blows, even to collisions, yet its weight is only one ton more than that of a steel wagon of the same capacity, whilst its cost is much less. For larger sizes, the advantages are all in favour of the concrete wagon. These include low maintenance and repair costs, and great resistance to corrosion. The latter has been the cause of a Lubeck firm employing concrete wagons for blast furnace slag, as the sulphur in this material rapidly corrodes steel and iron wagons. Another use of concrete is for repairing old wagons by building a concrete body on the old framework; wagons so repaired have been quite satisfactory.—*Zement.*

The Cambridge Road: Completed Section after Nine Months' Use by Traffic. (*See p.* 471.)

CONCRETE ON ARTERIAL ROADS.

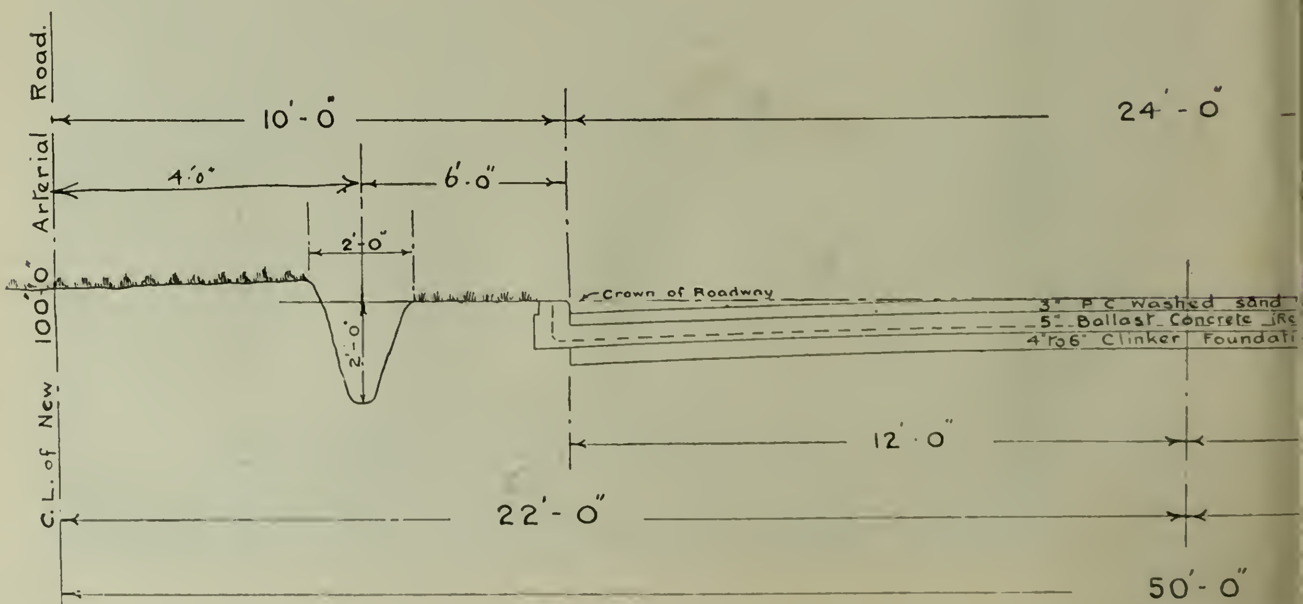
From the point of view of useful service—and that is the object which should always be borne in mind when work is put in hand, not so much because it is absolutely necessary, but in order to meet exceptional circumstances—the utilisation on road work of a considerable proportion of the unemployed during the period of trade depression which set in some two years ago was undoubtedly the best method by which distress could be relieved and some tangible material assets secured at the same time. More roads and better roads are urgently needed at the present time, and the developments in both the speed and weight of mechanically-propelled vehicles will render a first-class road system even more imperative in the near future if the trade of the country is not to be held in check. Many of the arterial road schemes which were started primarily to relieve unemployment are now in use, many others are rapidly nearing completion, and there is, we think, no doubt whatever that before they have been long in use the realisation of their value in enabling goods to be transported rapidly from one point to another will lead to many further road developments being undertaken, not as an urgent measure to ameliorate distress but as an urgent measure to assist trade and the general well-being of the country.

Practically without exception the new roads have been schemed in a broad-minded manner with a view to future requirements as regards width, the easing of gradients, and permanence of construction. As is shown by the numerous illustrations in previous issues of this journal, concrete is being used on a considerable number of the new roads, and if they prove to be as satisfactory as the many all-concrete roads which have been in use in this country for a long period of years, withstanding heavy traffic with no signs of serious wear, the local authorities concerned and the Ministry of Transport (which is paying half the cost) will have no cause to regret their enterprise in using what is in this country a comparatively new material for road construction. Perhaps the experience gained in the United States, where bare concrete is rapidly becoming the chief form of road, had some influence with the authorities; if so, the extraordinary wearing properties which the American roads have been found to possess indicates that there need be no qualms on that score in this country.

The Cambridge Road: Under Construction.

The road illustrated herewith is the section, seven miles in length, of the new London-Cambridge road from Downhills Lane, Tottenham, to the Hertfordshire boundary via Edmonton and Enfield, which, when completed, will provide a much-needed link between the North Circular Road and the eastern counties. This seven-mile section is now in course of construction under the direction of Mr. Alfred Dryland, M.Inst.C.E., County Engineer of Middlesex, by whose courtesy we were recently given facilities for seeing the work and taking the accompanying photographs. Mr. Dryland's representative on the work is Mr. J. A. Jameson, who is working in conjunction with Mr. Cuthbert Brown, District Surveyor of Edmonton. The complete scheme provides for a road 100 ft. in width over all, but for the present only half this width is being carried out. The section illustrated on this page shows the work now being proceeded with: from the right, the first 8 ft. is footpath, the next 8 ft. is as yet undeveloped, the carriageway is 24 ft. wide, and 10 ft. of undeveloped land is shown on the left, a total of 50 ft. When, in the future, the road is completed to the full 100 ft., the footpaths will be each 16 ft. wide and a strip of 20 ft. wide (suitable for a tramway) will separate two carriageways, each 24 ft. wide. The road varies from 12 in. to 14 in. in thickness, according to the subsoil. On a foundation of clinker varying from 4 in. to 6 in. thick, a layer of concrete, composed of 1 part Portland cement, 2 parts sand, and 4 parts ballast and shingle from 2 in. down to ¼ in., is laid in one course. On some of the earlier sections the concrete was laid in two courses over the clinker foundation, namely, 5 in. of reinforced ballast concrete with a surface covering of 3 in. of concrete formed of Portland cement, washed sand, and shingle, but that was abandoned in favour of the one-course method. The camber of the road is 1 in 48, or a rise of 3 ins. from the side to the crown. The reinforcement, supplied by Messrs. The British Reinforced Concrete Engineering Co., Ltd., of 1, Dickinson Street, Manchester, and Messrs. Brown & Tawse, Ltd., of 3, London Wall Buildings, London, E.C.2., is placed 2 in. from the surface. No expansion joints are used. The cost of the concrete and reinforcement worked out on the earlier sections at about 13*s.* per yard; but in the later sections, owing to the reduced cost of labour and materials, the cost is 10*s.* 6*d.* a yard. The kerbs are being formed separately of concrete cast *in situ.*

The completed sections are striking examples of the excellent road surface which concrete affords without any further covering, and consequently without additional expense. No longitudinal cracks whatever have appeared, and although on one or two short lengths there are a few transverse cracks, these



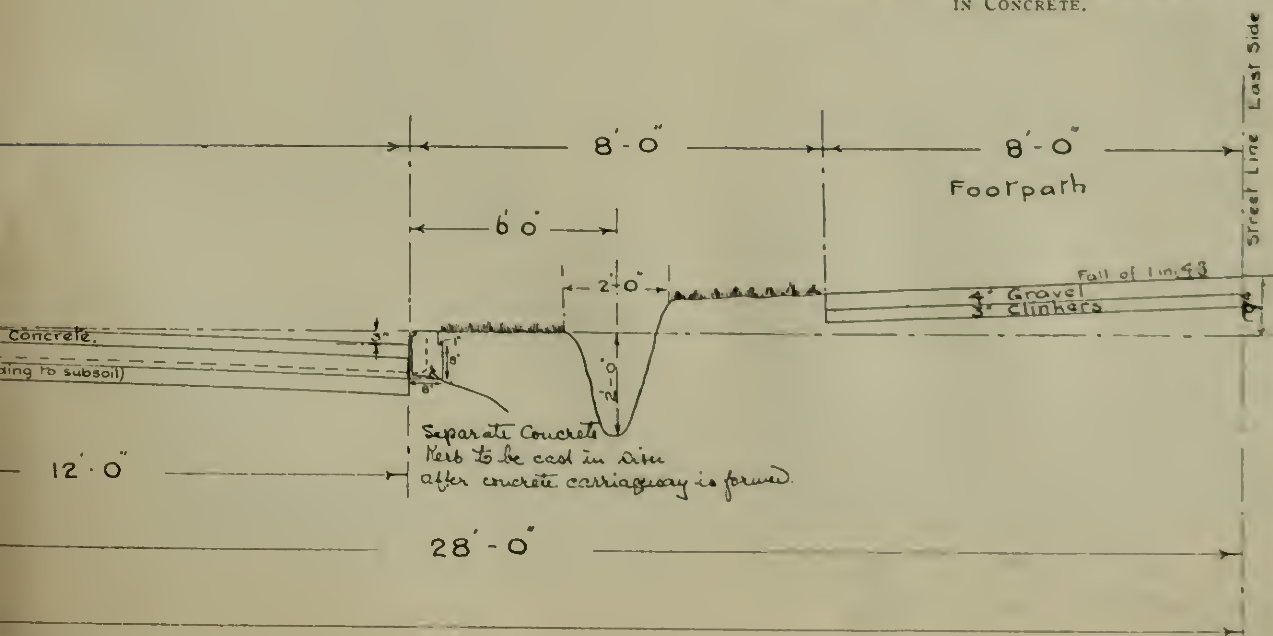
SECTION THRO

are so small as to be negligible ; in none of them can the blade of a small penknife be inserted more than a sixteenth of an inch, and they can hardly be the cause of any trouble in the future. It is important to note that although this work is nominally being carried out by unemployed and unskilled labour, all the concrete laying is being done by trained men ; the necessity for using skilled labour for this part of the work cannot be over-emphasised, and it has undoubtedly had a great deal to do with the success of the Cambridge Road.

The average rate of progress of the work of laying the road is 150 ft. a day of 8½ hours, and this rate is often exceeded. The plant consists of a Lakewood paving machine, with a capacity of 22 cu. ft. of dry material and from 13 to 14 cu. ft. wet, and a Lakewood petrol-driven tamper.

The speed with which the work is being carried out, and the excellent results obtained, reflect great credit on those responsible for the design and supervision, whose work on this road will, we are sure, pass from the pioneer stage to the time when it will be possible to point to the Cambridge Road as an example of the way in which carefully-designed and well-carried-out all-concrete roads will stand up to modern traffic—and that with certainly no greater initial cost than other types of road and with but a fraction of the maintenance costs.

SECTION OF CAMBRIDGE ROAD NOW BEING BUILT IN CONCRETE.



BRIDGE ROAD.

WAR MEMORIALS IN CONCRETE.

THE two war memorials illustrated on this page have been built in concrete at Eccles and Burham.

The Eccles (Kent) memorial, designed by Mr. Whitcombe, of Maidstone, takes the form of a clock tower, built of concrete blocks pre-cast in wooden moulds. The panels containing the inscription are also of concrete, and were made from plaster moulds; on one panel the lettering is raised, while on the other it is sunk. The total height of the memorial is 17 ft., and the base 4 ft. 6 in. square. An attractive surface, resembling Portland stone, has been secured by facing the blocks with find sand and Portland cement after they were taken from the mould.

The Burham war memorial stands 15 ft. high from ground level to top of cross, and is 5 ft. 6 in. square at plinth. Three 9 in. steps are formed on all four sides with a 6 in. rise, which were cast *in situ*, composed of 4 parts $\frac{1}{2}$-in. mesh ballast, 1 part sharp sand, and 1 part Portland cement. From above the steps to the projecting moulded cornice the memorial is built with pre-cast concrete blocks, 18 in. by 9 in. by 9 in., made on a block-making machine. The blocks are composed of 4 parts $\frac{1}{2}$-in. ballast, 1 part sharp sand, and 1 part Portland cement for the bulk, and 3 parts of sharp sand and 1 part Portland cement for the face, cast in one operation. The whole of the moulded cornice and stepping up to the cross, and the cross itself, were cast in wooden moulds composed of the same proportion of aggregates and cement as the blocks, and reinforced with $\frac{3}{4}$ in. diameter mild steel bars directly under the cross and $\frac{1}{2}$ in. diameter mild steel bars on each side, well laced together. The cross is also reinforced with $\frac{1}{2}$ in. diameter mild steel bars both vertically and horizontally, well dowelled into the stepping below. The four inscription panels are of rubbed Portland stone, 3 in. thick, inserted into grooves in the concrete blocks, with the names, etc., cut in and blacked. The panels are of lighter colour tnan the concrete, and add to the effect. This memorial was designed by Mr. F. Burren, of Burham.

A war memorial in concrete, which has been erected at Great Sankey, is illustrated on p. 450.

BURHAM (KENT) WAR MEMORIAL.

ECCLES (KENT) WAR MEMORIAL.

SOME CAUSES OF CRACKING AND DISINTEGRATION OF PORTLAND CEMENT CONCRETE.

By R. E. STRADLING, M.Sc., A.M.Inst.C.E., A.M.Am.Soc.C.E.

(*Lecturer in Civil Engineering, Birmingham University.*)

(*Concluded from p.* 398.)

III.—FAILURES DUE TO COMPOSITION AND PHYSICAL STATE OF AGGREGATE.

It will be convenient to consider these effects under the four headings of :—

(*a*) Water.
(*b*) Fine aggregate.
(*c*) Coarse aggregate.
(*d*) Artificial aggregates.

In general it can be stated that any organic impurities which may be present in any of these will in all probability cause failure. As an extreme example of this it may be noted that quite small quantities of tannic acid will cause complete disintegration. This has been pointed out by Professor D. Abram, and one or two preliminary experiments carried out at Birmingham University confirm this work.

(*a*) WATER.—There is very little doubt that one of the essentials of a sound concrete is clean water. The type of water which one is very tempted to use at times in practice is that found in pools and canals near the site. If this is stagnant, or even under many conditions if it is flowing, the chances are that it contains large quantities of injurious impurities. An example can be cited in the case of waters obtained from streams flowing near tanneries. The question of sea water has attracted a good deal of attention, and apparently no definite ruling can even now be laid down. Structures exist in which sea water was used in the making of the concrete, and these structures have lasted. Again, others have been built which have disintegrated badly. It seems safe to state that sea water should not be used and that *a priori* considerations would indicate that disintegration would follow its use. It would seem more than probable that in the setting of the cement the salts present in the water must crystallise out, and thus may cause a pushing apart of the materials of the concrete. Even if this does not occur there must remain, after setting, substances in the concrete which are easily soluble in water, and thus under the influence of rain or other forms of water will wash out and leave voids.

(*b*) FINE AGGREGATE.—Leaving the consideration, which has already been stated, of the effect of organic impurities we still have the possibility of dirty sand in the form of an admixture of clay and sand. In trying to mix concrete in which clay is present it is suggested that probably the real difficulty is to break up the clay aggregations and to surround the separate particles with cement. If these particles are of colloidal dimensions the task would appear practically impossible. This leaves centres in the concrete which are soft and easily deformed, hence forming a weak material. The writer would also hazard the suggestion that if much clay is present and not well mixed the cement surrounding a clay aggregation would, in setting, probably absorb water from the clay and contract round it, compressing it somewhat. If moisture can afterwards reach this clay it would swell, and hence have a bursting action on the concrete. In general, apart from clay, it can be definitely stated that the smaller the sand grains the more cement is required to give a strong matrix. If, on the other hand, enough fine material is not present the result is a porous concrete, since the voids between the larger aggregate cannot be filled. It is therefore absolutely essential to use suitable fine material if a sound concrete is required. An example has just come to the writer's notice in which concrete was made with a fine sand, clean and fairly sharp. This concrete could be crumbled in the fingers. An examination under the microscope showed that a very large proportion of the sand grains had never been touched by cement. The mix was 1 part cement, 2 parts sand, 3 parts gravel, and would have been quite sound if the sand had not presented a total of such an abnormally large surface to be covered.

(*c*) COARSE AGGREGATES.—The writer does not know of any material normally used for concrete which in itself, as found in Nature, is the cause of any disintegration. There are many, however, which as found are associated with the materials which do have a harmful effect. A large number of gravels contain organic impurities and clay, and as already indicated these things are probably harmful. Crushed rocks of various types usually form a clean aggregate, though one case of local interest has been brought especially to the notice of the writer. This is the quartzite found in the Midlands. It is a shattered rock, and the cracks are filled with large quantities of haematitic clay. This adheres as a coating to the fragments, and when mixed to form concrete prevents the cement from sticking to it. Whether there is also a chemical action is not certain, but there would appear to be some indication of this at times. Such a rock, in the writer's opinion, is very unsuited for concrete work unless thoroughly washed.

(*d*) ARTIFICIAL AGGREGATES.—Under this heading are included both fine and coarse aggregates, which are manufactured articles and not materials as found in Nature. These are of three general classes.

(i) Clay products; (ii) slags; (iii) coal products.

(i) *Clay Products.*—Broken brick is, of course, the chief aggregate of this type in this country. It forms an excellent concrete if clean and not too porous. If, however, insufficient cement is used and if broken brick of a porous variety is exposed to the weather disintegration can occur. The screenings from broken brick can be used quite well as a fine aggregate instead of sand.

(ii) *Slags.*—There appears little doubt that with certain precautions slags can make good concrete; in fact, very often a much stronger concrete than any other aggregate. But there is also no question that a great number of failures have followed from its use. In a blast furnace there is a compound or series of compounds of a similar nature to Portland cement clinker but with a lower percentage of lime and usually a higher percentage of alumina. Finely-ground slag will in itself act as a cement, and has been used in some cases with great success. Unfortunately, there is quite often a comparatively large percentage of sulphur present, and this is usually credited with being dangerous. Also, a large number of slags disintegrate on exposure to the weather. Before use these slags are allowed to weather for about six months and then screened. It is not worth while, for the present purpose, further to discuss the preparation of slag. The possible dangers after a period of weathering appear to arise from three possible conditions. (1) Sulphur content; (2) free lime; (3) fine screenings.

These need not be discussed very fully. The same problem arises here as that already mentioned in the problem of disintegration due to the cement itself. It would appear to be unwise to use the fine screenings in the place of sand. Such

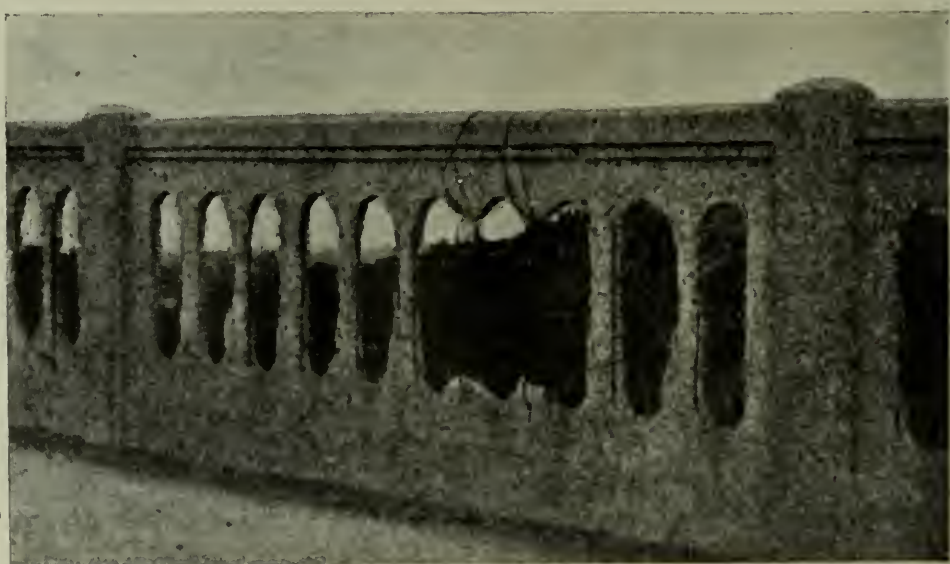


FIG. 6. FAILURE ON NASHVILLE BRIDGE.

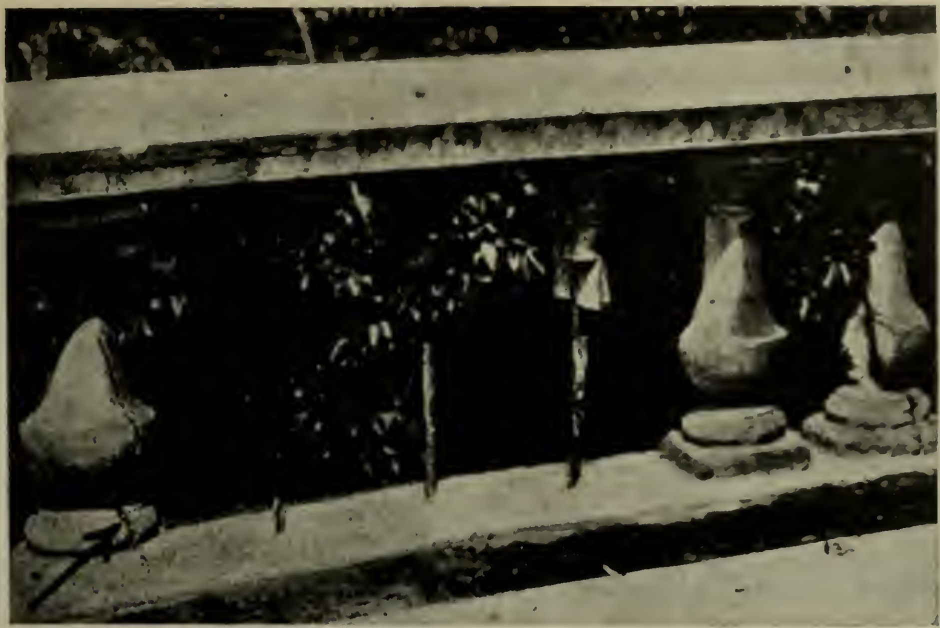


FIG. 7. FAILURE OF CONCRETE RAILING NEAR NICE.

a material is quite likely to act in the same way as the coarse particles of Portland cement, and may in addition be easily attacked by certain atmospheric conditions, and then, if high in sulphur content, become converted into calcium sulphate, which in large quantities is certainly harmful. So far as the available published data is concerned it seems certain that very strong concrete can be made and that no attack on the reinforcing steel can be definitely attributed to its use.

Some experiments were started some years ago at Birmingham University to obtain information on this point, and the following note is taken from data obtained by Professor Lea and the writer. It was found that bright drawn steel embedded in slag concrete was quite unchanged after six years, though stored under water. An examination of the concrete which has been broken shows one point very strikingly—the fracture always goes through the large aggregate, and not around it. In the case of most aggregates, such as gravel, broken stone, etc., the fractures occur through the mortar around the stone. Since the strength of slag concrete is usually greater than most other concretes it can fairly be assumed that the adhesion between the slag surfaces and the cement mortar is greater than between the latter and natural stone. As a slag is somewhat similar to a cement clinker, it is reasonable to assume that the extra adhesion is due to the hydration of the slag surfaces. An extremely valuable paper on this subject was read by Dr. J. E. Stead, F.R.S., before the Cleveland Institution of Engineers in November, 1919.

(iii) *Coal Products.*—Under this heading are included such materials as coke breeze, pan breeze, etc. The use of such material as aggregate gives a very light concrete, but usually very porous. It usually contains a very high percentage of sulphur, and if not carefully screened a very large amount of extremely fine material. It is well known that sulphurated hydrogen (H_2S) is given off when some of these aggregates are moistened, and the writer recently had on good authority an account of a rather abnormal failure of a floor due, he thinks, to this action. A floor made of breeze concrete was plastered underneath for the ceiling of the room below, whilst the breeze-concrete surface itself was used as floor surface. It became desirable, owing to wear, to cover this floor, and asphalte was used for the purpose. Very soon after the placing of this air-tight covering both this and the ceiling began to bulge, due to the accumulation of gas, and ended with the failure of the whole floor. With the present state of knowledge on these materials it would appear to be rather a risky matter to recommend their use. The use of old slag heaps is dangerous from this standpoint. It is often impossible without great expense to separate the useful material from the dangerous. Three cases of failure in the Midland area, due, the writer thinks, to this cause, have been brought to his notice during the past few months.

IV.—FAILURES DUE TO THE CONDITIONS TO WHICH CONCRETE IS EXPOSED.

It is the opinion of the writer that by far the greater proportion of failures experienced in practice may be placed under this heading, though often the exposure to some condition would not be harmful if one of the actions indicated in divisions (I) to (III) of this article had not taken place first. Concrete, as used in practice, is porous, and, due to this, is liable to suffer disruption when exposed to any liquids from which crystals can be deposited. The obvious case of water freezing in the pores of the cement at once suggests itself. In a like manner contact with sea water can cause a crystal growth.

There is one point in this connection which the writer would submit has not received sufficient attention. Over twenty years ago Le Chatelier showed that when a substance is under stress, in contact with a liquid unstressed, an increased solubility of the solid in the liquid is caused. If a condition occurs where the solid is in contact with a supersaturated solution a dissolving away of the solid at one point and deposition at some other of crystals of the solid will take place. Such a condition, it is submitted, may often be reached in engineering structures, e.g., above low tide in piers and jetties. The water left in the pores of the concrete gradually evaporates and at the same time dissolves a certain fraction of the concrete. This action may be continued until a saturated solution is obtained, then crystallisation starts, and if the concrete is at the same time under stress then in addition to the crystallisation in the pores the material itself is being abnormally dissolved.

Portland cement after hydration is essentially basic in character, and it is to be expected that any acid is liable to attack it. This is usually found to be the case, though sometimes the action is very slow and the resulting products are of such a nature as to prevent further action. Very little is known as to the effect of oils and fats on concrete.

The effect of atmospheric changes upon concrete is very marked. If concrete sets in air it contracts, and the figure often given for this is about ·05 per cent. On the other hand, if concrete sets under water it expands, and the order of this appears to be about ·01 per cent. Professor A. H. White has shown that even after twenty years' service as a street pavement a specimen taken up expanded if wetted and contracted when dry. At this age a total expansion of ·175 per cent. was obtained by successive wettings. The writer was informed of an interesting example of this in railway bridge practice. The ballast of a bridge was carried on two layers of concrete separated by asphalte. Great trouble was experienced owing to the top layer of concrete alternately expanding and contracting when exposed to wet and dry weather. It is obvious that such a type of construction does give every facility to the upper layer of concrete to move.

Fig. 8. Electrolytic Corrosion of Steel Reinforcement: Cracks in Lower Part of Girder.

The viscous fluid asphalte allows movement, and the arrangements for the drainage of the bridge will ensure that the concrete will be rid of water so soon as the bad weather has ceased. If hydrated cement is assumed to be colloidal in nature this kind of action appears reasonable.

Thus, the alternation of wet and dry weather is probably the chief source of cracking and ultimate disintegration of concrete. Once cracks are started other actions can then complete the work of destruction.

Closely allied in nature to these weathering effects are those due to exposure to a considerable rise in temperature. If this exceeds about 100° C. considerable contraction takes place, causing cracking and probably disintegration. If reinforced with steel the conditions are usually better if the temperatures are low, but much worse at higher ones.

Turning now to reinforced concrete, the questions of thickness of cover over the steel and the degree of porosity possessed by the concrete are of first importance. If moisture and air can reach the steel, rusting will occur—this results in the formation of an expansive compound which bursts the concrete off the steel. Such cases are illustrated in *Figs.* 6 and 7, taken from examples given in *Engineering News Record* recently. An examination of such failures makes one ask how such actions can actually be avoided. The writer suggests that, assuming sound materials, such cases usually have their origin in the formation of the fine contraction cracks. Such cracks must occur where ornamental designs are attempted giving very large variation in section at the various points. Then, if such construction is exposed to alternate wetting and drying, and has a centre reinforcing rod, some cracking is almost inevitable—and once started these will probably increase. In sea work rusting of the steel very often takes place, and in most cases above the low-water line. Undoubtedly the steel is reached by cracks started by one of the actions mentioned earlier. A rich, impervious concrete is absolutely essential for sea work, and very necessary for all external concrete.

One other condition is worth consideration as a possible source of corrosion of steel in concrete. This is the electrolytic action due to leakage from an electrical circuit in the building. The necessary factors for this action to take place are (1) contact between the steel reinforcement and an electrical conductor at a different potential to that of the building; and (2) moisture in the concrete.

Some examples illustrating this are shown in *Figs.* 8 and 9 taken from an article by Dr. C. H. Desch in *Concrete and Constructional Engineering* for March, 1911, in which a specific example is well summarised and illustrated.

In conclusion, the writer would summarise the preceding notes on the causes of failure in concrete as follows :—

FIG. 9. ELECTROLYTIC CORROSION OF STEEL REINFORCEMENT: CONCRETE FORCED OFF STIRRUPS OF BEAM.

(1) By far the greater number of failures are due either to faulty workmanship or the condition to which the work is exposed.

(2) Only a very few can be traced to bad materials.

(3) If unsound cement is used the failure is likely to be a very complete one, but this cause need not be feared with a cement passing the British Standard Specification.

(4) It is extremely difficult, and in most cases impossible, to trace the cause of disintegration and cracking of concrete just from an examination of a small sample cut from the work.

(5) A close examination of the site and a detailed and accurate history of the work is essential if a correct judgment is to be made.

(6) Cracks caused by changing weather conditions on members with rapid changes in section are likely to be more serious than usually thought.

(7) In sea work trouble is most likely to occur just above low-tide level and any position which is likely to get swept by waves or spray occasionally. The porous nature of concrete is its chief enemy when exposed to this or any other "crystallisation action."

(8) The writer has not been able to obtain direct evidence of the disintegrating actions of sulphur compounds present as gypsum except when very abnormal quantities are used (8 to 10 per cent. added to cement).

(9) "Earths" on electrical systems in reinforced concrete buildings should be very carefully watched. Moisture is an essential factor in electrolytic actions, and evidence of corrosion is most likely to be found at the dampest portion of the building first.

BOOK REVIEWS.

Real Mathematics. By Ernest G. Beck.
Oxford Technical Publications. 15s. net.

The author states that his book is intended to be read in conjunction with, and not to supersede, the ordinary mathematical works.

It attempts rather to make mathematics more real and solid—"to show the thing as an actual, tangible reality, instead of as a collection of rigid and unrelated rules and formulae."

The usefulness will obviously depend on the actual mathematical equipment of any individual reader, and one would not like to say with certainty how many students will find it a help.

Personally, the writer rather found the author explaining matters at great length where he saw no difficulty, which is sometimes rather confusing—but then both at school and at the University he had the almost unfair advantage of the most clear and excellent teachers. It is of course a fact that the teaching of mathematics has advanced tremendously in the direction desired by the author during the last generation, and one wonders how far Mr. Beck's explanations are solutions of difficulties commonly felt by the average student of some years ago which would not be felt by the average student of to-day.

The only answer to this will be supplied by the students of to-day.

O. F.

Tabellen fur die Einflusslinien und die Momente des durch laufenden Rahmens.
(Published by W. Ernst and Sohn, Berlin. Price in England, 90 marks.)

Every conscientious engineer engaged in concrete regards it as a part of his duty to use materials as sparingly as possible, provided ample security be ensured. This is particularly the case with structural framework in either steel or reinforced concrete.

The tables in this volume are intended to reduce the calculations of stresses and moments to a minimum, and so far as we have checked them they appear to serve their purpose well. The tables are arranged for structures with one, two, three, or four openings respectively. For those constructional engineers who can make good use of such a table, printed in German, the volume is cheap at the present rate of exchange.

CEMENT NOTES.

By Our Special Contributor.

The Chemistry of Cement.

Strenuous efforts are being made by research workers to raise the technology of cement from its present empirical and almost rule-of-thumb basis to the higher regions of exact science which would enable the manufacturer of cement to know precisely what chemical compounds he should seek to produce, and what to avoid, in the interests of quality. One attempt was referred to in these notes in January, and we now have another, in the writer's view a more successful one, in the *Journal* of the Franklin Institute, where an American authority on cement, Mr. P. H. Bates, writes on "The Application of the Fundamental Knowledge of Portland Cement to its Manufacture and Use."

The research work of which Mr. Bates gives an account is a development of the purely laboratory and highly-scientific investigations previously carried on at the Geophysical Laboratory of the Carnegie Institution at Washington, and it was sought to apply on a large scale some of the generalisations which had emerged from this work. To this end an experimental rotary kiln (20 ft. by 2 ft.) and grinding plant were provided, and various mixtures of cement raw materials were prepared, calcined, and ground. The resulting cements were tested, and the relation between chemical composition and quality observed. Some of the results of this investigation are already well known, for example: tricalcium silicate sets and hardens like ordinary Portland cement; dicalcium silicate does not commence to harden for two or three weeks, although it attains in three or four months the same hardness as commercial cement; tricalcium aluminate hydrates almost instantaneously, but without actually setting or hardening.

In view of these results, the first obvious consideration was whether tricalcium silicate alone could not be produced in cement without the apparently useless dicalcium silicate and tricalcium aluminate, but the answer to this was that the cost of producing tricalcium silicate alone was prohibitive, while by permitting the presence of alumina a cheap and abundant siliceous raw material like clay could be used, and the formation of a certain amount of tricalcium silicate was facilitated by the aluminous flux which would be formed. In the progress of the investigation some fifty cements were made in the experimental rotary kiln, and the composition was varied to alter the respective proportions of the three prime compounds—tricalcium silicate, dicalcium silicate, and tricalcium aluminate. The proportions of these in any cement cannot be ascertained by chemical analysis, but only by petrographic examination of thin sections of clinker.

Among the interesting results which emerge from this study is that the proportion of the most effective constituent in Portland cement, viz., tricalcium silicate, cannot be deduced from its proportions of lime; e.g., a cement containing 64·5 per cent. of lime was found to contain 29·5 per cent. tricalcium silicate, while one containing 64·1 per cent. lime contained 61·8 per cent. tricalcium silicate.

The observations as a whole show very distinctly the value of tricalcium silicate in producing strength in a cement, and this is especially marked in tests of concrete at four weeks. At five years the cements with the maximum of tricalcium silicate are still the best, but not to the same degree, thus showing that dicalcium silicate comes into play in course of time.

The figures also show that for good strength at four weeks the proportion of tricalcium silicate should not be less than 33 per cent., nor that of dicalcium silicate more than 33 per cent., and it is interesting to note that these proportions when calculated out to percentages of lime and silica are close to those occurring in manufacturing practice.

The practical difficulties of increasing the proportion of tricalcium silicate still remain. The straightforward method is to increase the proportion of lime in relation to that of the silica, but this involves a higher burning temperature than is compatible with modern economical practice. There is, however, the alternative of calcining at a lower temperature for a longer period if the right kind of kiln could be evolved for this.

The Bureau of Standards (U.S.A.) is also experimenting on the lines of mixing the fuel with the raw material, as there are indications that this procedure may be effective in producing the conditions necessary for the formation of tricalcium silicate. It is interesting to note that this is a method which is in actual practice on the Continent, and its advocates claim it to be superior in economy and equal in quality to rotary kiln practice. This in its turn may lead to fusion of Portland cement instead of clinkering.

On summing up the position, we find that the impression that tricalcium silicate is the most desirable constituent in cement is confirmed, but there is still no knowledge as to how the proportion of this constituent can be increased without causing the cement to be unsound. Some scientific explanation is also needed of the fact that the cements which exhibit the greatest strength at ages up to seven days are those with high proportions of alumina.

CONCRETE AT COUNTY AGRICULTURAL SHOWS.

In the minds of many people, perhaps the majority, concrete is associated principally with great constructional undertakings, such as docks, harbours and breakwaters ; or it is regarded as suitable chiefly for foundations and other mass work. Wider knowledge would teach that concrete, in addition to being invaluable for work of this nature, is also particularly applicable to an infinite variety of minor uses on the estate and farm, in the house and garden, in town and country.

With a view to demonstrating the value of concrete for such purposes, the Concrete Utilities Bureau, of 35, Great St. Helens, London, E.C.3, has during recent years taken a large stand at the Royal Agricultural Show, where much useful educational work has been done. This year, however, it is departing from this practice, and is, instead, exhibiting on a rather smaller scale at many of the principal county Shows. The Shows which have already been visited are the Oxfordshire Agricultural Show (held at Thame on May 17 and 18), the Suffolk Agricultural Show (Felixstowe, June 1 and 2), the Essex Agricultural Show (Chelmsford, June 7 and 8), and the Royal Norfolk Show (Diss, June 21 and 22). The complete programme includes the Peterborough Agricultural Society's Show (to be held at Peterborough on July 11, 12 and 13), the Bedfordshire Agricultural Show (Ampthill, July 20), the Hertfordshire Agricultural Show (Hatfield, July 27), the Chesterfield and East Derbyshire Agricultural Show (Chesterfield, August 9), and the Royal and Central Bucks Show (Aylesbury, September 14).

The exhibits, which are transported from one Show to another in a steam lorry and trailer, include a pigsty, cowstall, posts for various types of fencing, gate posts, pig troughs, tanks, garden frames, pipes, roofing tiles, cement-asbestos rainwater goods, spurs, and the moulds in which many of these articles are made. Great interest has been shown in this collection, and the demonstrations of the moulding of concrete articles which have been carried out at frequent intervals during the Exhibitions have been watched by many hundreds of enthusiastic and appreciative spectators.

CONCRETE PROPS IN MINES.

The use of concrete props instead of wooden ones in coal mines still continues to increase. The shape of the concrete props varies greatly, but in essentials they do not differ much from the wooden ones which they displace. It has been objected that concrete props do not yield to pressure, and so are inferior to wood ; this difficulty has been overcome by placing wooden blocks to distribute the pressure. It has also been stated that concrete blocks are more difficult to fix in position ; this is not the case when suitable means are used for fixing them—they can be replaced as easily as wooden props, repaired more easily, and are far more secure, as their strength does not diminish with age to anything like the same extent as wood.—*Revue de Matiéres.*

DETERIORATION OF STRUCTURES IN SEA WATER.

An interim report has been issued by the Committee of the Institution of Civil Engineers which has been investigating the subject of the deterioration of structures in sea-water since 1916. The first report was issued in 1920, and from the interim report (London: H.M. Stationery Office, price 2*s*. 6*d*. net) we take the following abstracts of various reports:—

THE ADMIRALTY.

Mr. L. H. Savile, M.Inst.C.E. (Civil Engineer-in-Chief's Department, Admiralty), summarising the results obtained, says it might be said that the deterioration of sea structures, apart from ageing and fair wear and tear, may be due to any of the following causes: (1) faulty design, (2) faulty workmanship, (3) unsuitable materials, and (4) exterior agencies.

Important considerations under these headings are: (*a*) The use of poor concrete in exposed situations; (*b*) neglect of reasonable precautions in regard to waterproofing, either by asphalte or other impervious material, and (*c*) faulty judgment as to the use of timber, stone, or concrete for various purposes. It seems to be established that unless concrete is practically impervious the percolation of sea-water through the interstices invariably leads to deterioration.

As regards the fourth cause, that is, exterior agencies, this may be divided into three subheads, namely: (*a*) Chemical, i.e., atmospheric; (*b*) animal, i.e., boring organisms, and (*c*) mechanical, i.e., demolition, attrition, etc. Experience in regard to these headings is sufficient to enable some general conclusions to be drawn so far as Admiralty work is concerned.

In regard to (*a*) the action takes place chiefly on iron and steel structures, and the portions affected are those between high and low water and above high water especially. The proper application of preservatives in such a position is difficult owing to the salt dampness. One method of overcoming this, which has been tried on a small scale and found to be reasonably successful, is thoroughly to dry and heat the surface of the steel with a blow-lamp immediately before the preservative is applied. This has also been tried with success where it has been necessary to apply tar to parts of structures between high and low water, and which otherwise do not dry out sufficiently. This action of the weather above high water is particularly noticeable also in ferro-concrete structures. The vast majority of rust spots occur in this position, and particularly on the underside of beams, where, through faulty workmanship, the stirrup has dropped in the mould during concreting. The Admiralty is emphatically of opinion that in exposed positions the least cover for reinforcement—even where the greatest pains are taken to secure good work —should not be less than 1½ in., and preferably 2 in., in order to allow for those practical exigencies which are inseparable from normal experience.

The third cause of deterioration, viz., demolition, attrition, etc., is due to the pounding action of the waves, and the thrash of wave-borne shingle and sand. As a general result the solidity of Admiralty structures and the standard of excellence demanded during construction have ensured permanency as regards the former, but instances of marked deterioration have been noted consequent upon the "thrash" of sand and shingle, and in this case also the golden rule seems to be to use only the very best materials that can be obtained and to take extraordinary care as regards the execution of the work. As much of the latter is necessarily done *in situ* between high and low water, still further care is necessary on this account. It is the Admiralty experience, however, that more might be done in the way of preparing concrete in mass or blocks on land, and afterwards transporting it to the site. The resulting air-dried concrete is stronger and more reliable when placed in position.

DEVONPORT DOCKYARD.

Dealing with the works at H.M. Dockyard, Devonport, Mr. G. P. Hayes, O.B.E., M.Inst.C.E., says reinforced concrete has satisfactorily withstood the action of sea organisms, both in the Hamoaze and Cattewater, and also of sea water where the matrix has been of good quality and homogeneous throughout, but where the cement has been insufficient destruction is taking place. A landing jetty constructed in 1913 of ferro-concrete throughout is considerably covered with barnacles between tide levels, but its condition is practically perfect. Where portions have been broken off the surface by abrasion the interior is clean and hard. There are very few rust spots. The superstructure of a jetty is supported by 26 in. by 13 in. ferro-concrete members forming the upper portion of cast-iron piles, the junction being about low water level of ordinary tides. The piles were erected about sixteen years ago to replace some timber members and are in very good condition, and practically no deterioration of any description is apparent. Abrasions show good hard interior, and there are very few rust spots.

Further up the Estuary, at Moon Cove, there is a 14 in. by 14 in. ferro-concrete pile jetty erected about the same period in very sound condition.

At Weston Mill Lake a landing pier was constructed in 1911 of ferro-concrete throughout. There the mixing was not homogeneous throughout ; patches, and in some cases fairly large patches, of the surface have broken away, exposing a very soft interior, the grains of quartz being quite free of any mortar, with consequent destruction. Further, there are many rust spots.

With respect to the condition of the concrete above high water to deck level, and of the deck itself in open wharf or jetty work, this is very good ; there are a few fine longitudinal cracks on the underside of the raking struts of jetty at Weston Mill Lake, and some fine longitudinal cracks in the bearers of the decking of the Mount Wise Jetty, but nothing of importance. The surface of the decking at the latter place is also wearing better than at the former.

At Turnchapel, Cattewater, the surface of the reinforced concrete wharf has been continuously covered with oil since it was brought into use in 1912, but no deterioration is to be observed.

Mass concrete is subject to be bored by *Saxicava rugosa*, but evidence points to the conclusion that it is not a favourable material for this mollusc, the chambers and animals found are not many, and never when there is a softer material in the immediate vicinity. At the Breakwater none was found in the concrete blocks, but a few have bored into the concrete of the Batten Breakwater, and again in the concrete at Turnchapel.

KARACHI PORT TRUST.

Mr. W. H. Neilson, M.A., M.Inst.C.E. (Chief Engineer to the Karachi Port Trust), states that four samples of concrete have been obtained from the Manora Breakwater. Two of them were taken off the big blocks above low water, about half-tide, and two were broken off from below low-water level. This breakwater, composed of cement concrete, with an aggregate of limestone pebbles, was built between 1870 and 1873. These specimens show that there is a dense incrustation on the outside of various molluscs and seaweed, both above and below low water. When the aggregate is near the surface the pholas has attacked it, but in no case has perforation taken place into the mortar, except for short distances. Such penetration is evidently for the purpose of reaching the larger pebbles, and it may, no doubt, be safely said that concrete is not liable to attack by these molluscs, and that if the aggregate had been smaller no such penetration would have occurred.

BRISBANE.

Mr. E. A. Cullen, M.Inst.C.E., gives some information further to that contained in the first report in regard to some test slabs of reinforced concrete under a wharf in Brisbane River. These eight blocks were placed entirely in the shade beneath a wharf in November, 1917. The water is practically as salt as sea water, and its temperature varies from about 35° Fah. in mid-winter to 90° Fah. in midsummer. The slabs are partly immersed at every tide, as the bottoms are 2 ft. 3 in. below mean high water level. They were cast with care, but without taking any special precautions, so as to represent good practical work. Each block was 4 ft. 6 in. in length by 6 in. square. The reinforcement consisted of steel bars ⅝-in. in diameter, fixed together with small 8-gauge wire brackets. The steel bars were so placed that the cover over Blocks Nos. 1 and 2 was ½ in. thick, over 3 and 4 1 in. thick, over 5 and 6 1½ in., and over 7 and 8, 2 in. in thickness. Blocks Nos. 1 and 2 were made up with mortar only ; no gravel being used in this case, because of the small amount of cover over the steel. The following table gives the various mixtures employed and the condition of the concrete on August 31, 1920.

No. 1. Made 27.9.17; cover ½ in.; mixture 4 sand 2 cement: Rust spots and cracks 3 ft. long at front-downstream arris. Crack $\frac{1}{16}$ in. wide at worst place.

No. 2. Made 27.9.17; cover ½ in.; mixture 4 sand 3 cement: Rust spots and cracks 6 in. long at the bottom downstream corners. Crack $\frac{1}{16}$ in. wide.

No. 3. Made 3.10.17; cover 1 in.; mixture 3.2.1: Rust spots and crack 2 ft. 6 in. long at front-upstream arris.

No. 4. Made 3.10.17; cover 1 in.; mixture 5.4.3: Crack 2 ft. long at front-upstream arris open $\frac{1}{32}$ inch.

No. 5. Made 8.10.17; cover 1½ in.; mixture 3.2.1: Rust spot at front-upstream arris.

No. 6. Made 8.10.17; cover 1½ in.; mixture 5.4.3: No sign of rust or cracks.

No. 7. Made 12.10.17; cover 2 in.; mixture 3.2.1.: No sign of rust or cracks.

No. 8. Made 12.10.17; cover 2 in.; mixture 5.4.3.: No sign of rust or cracks.

CORRESPONDENCE.

REINFORCEMENT FOR CONCRETE.

Sir,—As you are doubtless aware, for years I have been advocating the employment of steel bars having a high yield point and buckling resistance, in preference to ordinary mild steel bars having a low yield point and buckling resistance, for reinforced concrete, and thereby economising steel by calculating for a higher stress on the high yield point steel with as great a safety factor as calculating for a lower stress on mild steel bars.

Mathematical and theoretical engineers claim that by working at a higher stress on steel there is no saving, as the thickness of concrete must be increased because the height of the neutral axis is increased. This would be so if the steel were all of the same tensile resistance, but how can it be so if a steel having an ultimate strength of 80,000 lb. tensile resistance is stressed to 20,000 lb. to the square inch, and a steel having 60,000 lb. tensile resistance is stressed to 16,000 lb.? In one case, for the sake of argument, an inch diameter round bar might be employed, whilst in the other, perhaps only a ⅞ in. diameter bar, but the yield point and ultimate strength of each is the same, or possibly greater, the bars having a lesser area of steel; therefore, the neutral axis is unaltered.

Progress is often retarded through the lack of practice of those who are purely mathematical or theoretical engineers, and the individual who has gained his knowledge through practice is often held back by them to the detriment of the engineering world. There seems to be too much theory and mathematics in reinforced concrete and not sufficient development through practice.

Brown & Tawse, Ltd.
per A. W. C. Shelf.

Sir,—The letter from Mr. Shelf advocating high-tension steel at high stresses could have passed unchallenged had it not been for the somewhat provocative remarks about too much theory and mathematics in reinforced concrete. Yet a cursory examination of Mr. Shelf's letter reveals the fact that his argument is entirely theoretical, the only difference between his theory and the ordinary one being that his is wrong and not in accordance with fact. He states that if a small rod of high strength is used instead of a large rod of smaller strength the neutral axis can remain in the same place. The position of the neutral axis depends on the relative extension on the tension side to the compression on the compressed side. The extension depends on only two factors, the stress and Young's modulus. Experiments show that high-tension steel has practically the same Young's modulus as soft steel. Hence, an increased stress means an increased extension, which involves a raising of the neutral axis. The properties of high elastic limit and high strength do not, unfortunately, carry with them a high Young's modulus, and therefore within the elastic limit (within which we always work, of course) the bar with the higher stress necessarily has the greater elongation.

Oscar Faber.

WHAT IS THE USE OF THE MODULAR RATIO?

By H. KEMPTON DYSON.

[*Concluded.*]

The following data relates to the author's theory :—

Symbols (Referring in some instances to *Figs.* 27 and 28):

A = area of tensile reinforcement (in sq. in.).
A_1 = areal ratio, i.e., ratio of A to bd, therefore $A_1 = A/bd$ and $A = A_1bd$.
a = arm of resistance moment (in in.).
a_1 = arm depth ratio $= a/d \therefore a = a_1d$.
B = bending moment of the external loads or forces (in lb. in.).
b = breadth of rectangular section or flange of a tee-section (in in.).
c = compressive strength (maximum) on the compressed edge (in lb./in.^{2}).
C = total compressions, i.e., summation of compressive stresses.
d = depth (effective) of member (in in.), i.e., distance from extreme compressed edge to centre of tensile reinforcement.
l = length of the effective span of a structural member subjected to bending (in in.)
n = distance to neutral axis or to limit of compressed part from extreme compressed edge.
n_1 = neutral axis ratio $= n/d \therefore n = n_1d$.
R = resistance moment of the internal stresses in the bent member (in lb.-in.).
R_c = resistance moment of compressive stresses.
R_t = resistance moment of tensile stresses.
T = total tension, i.e., summation of tensile stresses.
t = tensile stress (maximum) on the extended edge or on the inforcement (in lb./in.^{2}).
W = total weight to be carried on the member (in lb.).

TABLE A.

No.	Function.	Form of Stress Distribution. Elliptical.	Parabolic.	Triangular.
1	C	$\frac{\pi}{4} bcn = \cdot 7854bcn_1d$	$\frac{2}{3} bcn = \cdot 66bcn_1d$	$\frac{1}{2}bcn = \cdot 5bcn_1d$
2	T	$tA = tA_1bd$	$tA = tA_1bd$	$tA = tA_1bd$
3	n_1	$\frac{4}{\pi} A_1 \frac{t}{c} = 1\cdot 27A_1 \frac{t}{c}$	$\frac{3}{2}A_1 \frac{t}{c} = 1\cdot 5A_1 \frac{t}{c}$	$2A_1\frac{t}{c}$
4	$d - a$	$\frac{4n}{3\pi} = \cdot 4244n_1d$	$\frac{3}{8}n = \cdot 375n_1d$	$\frac{1}{3}n = \cdot 33n_1d$
5	a_1	$1 - \cdot 4244n_1 = 1 - \cdot 54A_1\frac{t}{c}$	$1 - \cdot 375n_1 = 1 - \cdot 5625A_1\frac{t}{c}$	$1 - 33n_1 = 1 - \cdot 66A_1\frac{t}{c}$
6	minimum value of a_1	$\cdot 5756$	$\cdot 625$	$\cdot 66$
7	$\frac{R_c}{bd^2}$	$\frac{3}{16}cn^2a_1(1-a_1) = 1\cdot 85ca_1(1-a_1)$	$\frac{16}{9}ca_1(1-a_1) = 1\cdot 77ca_1(1-a_1)$	$\frac{3}{2}ca_1(1-a_1) = 1\cdot 5ca_1(1-a_1)$
8	$\frac{R_t}{bd^2}$	tA_1a_1	tA_1a_1	tA_1a_1
9	$\frac{R}{bd^2}$	$tA_1\left(1 - \cdot 54A_1\frac{t}{c}\right)$	$tA_1\left(1 - \cdot 5625A_1\frac{t}{c}\right)$	$tA_1\left(1 - \cdot 66A_1\frac{t}{c}\right)$
10	limiting value of A_1	$\cdot 7854\frac{c}{t}$	$\cdot 66\frac{c}{t}$	$\cdot 5\frac{c}{t}$

It will be noted that as the compressive stress and tensile stress up to the limiting percentage of steel will reach their ultimates at the same time, we can with that limitation get the simple formula No. 9 in the above table. From this data *Fig.* 29 has been plotted for triangular stress distribution for comparison with the ordinary theory. The dotted line shows the resistance moments obtained with certain percentages of steel at the working stresses stipulated in the London County Council Regulations. For the critical percentage, as it has been called (and by some persons the economical percentage), namely, that percentage

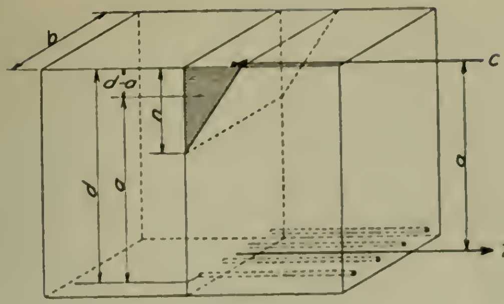


FIG. 27.

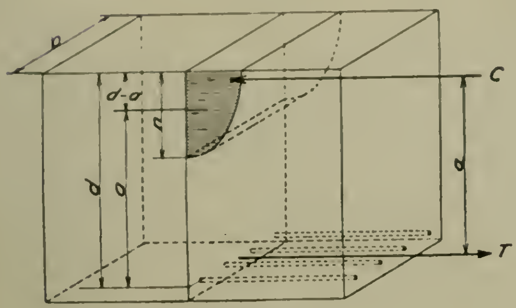


FIG. 28.

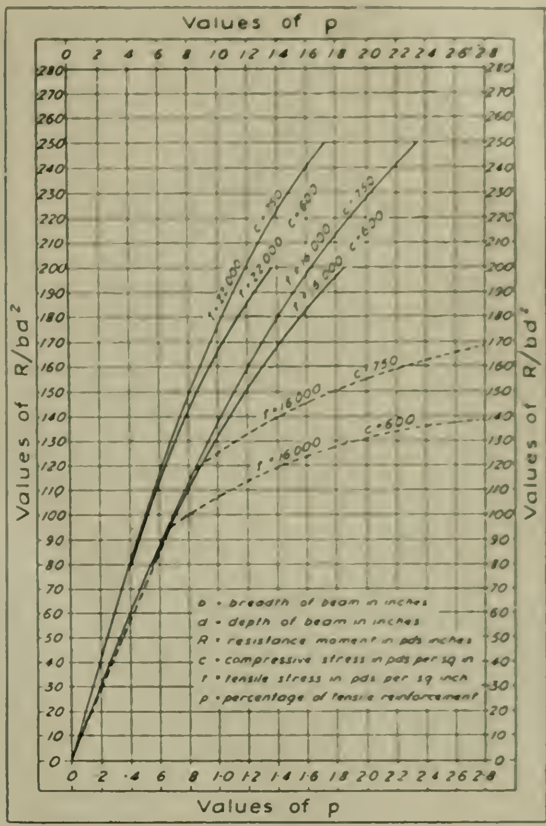


FIG. 29.

of reinforcement with which the stress in the steel and the stress in the concrete reach their limits, both theoretical treatments get the same results. Below the critical percentage there is very little difference as regards the moment of resistance, and most structures that have been built of recent years have been designed with the steel limited to the critical percentage or less. It is only when working on big percentages or with specially strong steel that the author's theory departs so greatly from the other. This is shown on the diagram by the curves above the critical percentage of the ordinary theory.

With the ordinary theory the economical limit is below where the formula for use becomes that for the moment of resistance in compression. The steel, according to that theory, above that limit cannot be stressed to the full, though the concrete can. There is, therefore, very little advantage gained from increasing the amount of steel beyond the critical percentage. In the author's theory, however, the increasing resistance moment obtained from an increasing amount of steel goes on much as before, though with some reduced effect, the line curving round gradually. The author's line, however, does not go on interminably like the other. It has to be stopped when a percentage is reached that gets the maximum compressive resistance out of the concrete. Thus it shows the point at which if any more steel is inserted it will give no greater strength.

One criticism may be that the author's method is all very well for the computation of the ultimate resistance moment, but it does not afford a means of determining working stresses with loads considerably less than the ultimate, and that the ordinary theory, however far wrong it may be as regards the ultimate strength, does tend to give some indication of the working stresses at working loads. This might be said to be a justification for the adoption of the factor termed the modular ratio, though seeing that with an ordinary working stress of, say, 16,000 lb. in.^{2} in the steel the concrete must be cracked, and therefore a reinforced concrete member must be acting as a frame or truss rather than as a beam; any calculation based on assuming it to be what it is not must be erroneous.

If, however, we are abolishing the use of the modular ratio, what are we to put in its place to afford some idea of the working stresses induced by any load considerably less than the ultimate? The author wishes to meet, if he can, the prejudices of those trained to thinking in terms of working stresses rather than in working loads determined by taking factors of safety upon the ultimate strength. *Fig.* 30 is prepared with that object. From an inspection of tests such as those of Prof. Talbot, it would appear that it is sufficiently accurate to assume that, for either small or large percentages of reinforcement, at very early stages in the loading the arm will approximate to ·82 of the effective depth. If the distribution is triangular that means that the compression will be taken on ·54 of the effective depth. If the beam were of homogeneous material the amount in compression would be ·5 of the depth. The provision of steel reinforcement in itself causes the neutral axis to come down. Then, again, the concrete on the underside of the bars will act also to bring the initial position of the neutral axis lower than ·5 of the effective depth. In the early stages of loading the position of the neutral axis will keep near to the initial position. In the final stages of loading, however, the depth of the part in compression will be near that calculated by the author's method. So if we find the ultimate arm by that method and take ·82 as the initial arm depth ratio we can pick out the proper line from *Fig.* 30. From a study of tests the author suggests that the variation of the arm at intermediate stages should be sufficiently nearly given according to the curves shown in the figure, which is drawn so that when the working load is ·4 of the ultimate, or, to put it another way, when the factor of safety is 2·5, the depth of the part in compression will be half-way between the initial position of the neutral axis and the final position of the compressed depth. Between the terminal points curves are drawn as segments of parabolas, with the apices at the initial and final points. It is suggested that for early stages of loading a sufficiently accurate result in analysing tests will be obtained by using this diagram in connection with triangular stress distribution. At a middle stage parabolic distribution would be more accurate, while in the final stages of loading elliptical stress distribution should be used.

Now, apart from what has been said, are there any other special novelties to note with this new theory ? The most interesting feature to the author's mind is one conclusion that it leads to, namely, that the modular ratio of the concrete and the steel can be consigned to limbo. All that matters is that the steel shall be capable of carrying the tension and the concrete the compression. Thus, as the steel has merely to carry the total tension, if we were to use very strong steel we could insert quite a small amount, and it would serve just as well as a large quantity of a weaker steel. That is a justification for those who have been urging for many years the advantages of such special steels. Tests have been made with drawn wire fabric, by firms manufacturing such material, which clearly indicated that there was some virtue in such materials, for smaller quantities gave as good results as larger quantities of mild steel, and alternatively, if the same quantities were inserted, those slabs in which drawn steel was employed carried bigger loads than those reinforced with mild steel. Specially strong steels are generally more expensive than ordinary mild steel, but their extra expense appears to be warranted by the economy that they effect.

Another striking feature is that, as shown in *Fig.* 29, whereas the ordinary theory indicates that for fairly high percentages of steel the moment of resistance is very little increased beyond that at the critical percentage, the new theory makes the moment of resistance increase almost as rapidly as before. This indicates that we can use with advantage more mild steel than we have been in the habit of using, or, alternatively, we can use, say, the same quantity we have been using, but stronger steel, and that we can with economy reduce the depth, or alternatively, with the same depth adopt greater spans.

In slabs there is a considerable economy effected by reducing the depth and increasing the quantity of steel. That happens to be what was advocated by early pioneers. In early designs the slabs were made much thinner than we have been making them. Cottançin, who built some wonderful structures in Paris and elsewhere, used thin slabs about 2 in. thick for quite considerable spans, and indeed was singular in claiming that reinforced concrete was one of the lightest forms of building construction known, whereas we have been accustomed to consider it as rather heavy. This newer theory would find some explanation for Cottançin's work and his contentions.

When elliptical stress distribution is adopted the author would in practice reduce the permissible stress on the concrete below that usually allowed where triangular distribution is assumed, because tests on cylinders or prisms whose height is at least twice the width show that the true crushing strength is about 80 per cent. of the values derived from cubes. The effect of working to the lower stress is to give much the same values as for triangular distribution with a higher stress.

Tee Beams.

In the current theory a great deal is made of elaborate formulæ for the resistance moments of T-beams. It would be easy for the author to provide formulæ of a similar kind devised in conformity with his particular theory, but from a practical point of view such formulæ are not of general application and can be omitted. As regards T-beams, it is common knowledge to designers that it is economical as a rule to make T-beams as deep as head room will allow. The result is that the concrete of the flange of a T-beam is sufficient to take all the compression at a stress which is often a good deal less than the maximum allowable. The percentage of steel employed is therefore comparatively small, such percentage being reckoned in regard to a nominal area found by multiplying the breadth of the flange by the effective

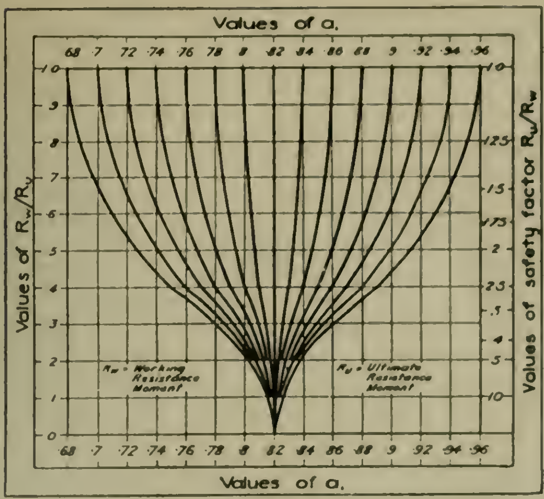


FIG. 30.

FIG. 31.

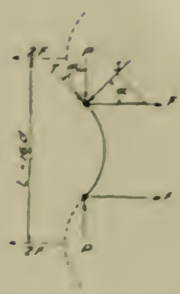


FIG. 32.

depth of the beam. Therefore, in an ordinary economical design a low percentage of steel will be employed, giving as a rule a low stress even according to the ordinary theory ; by the author's method the flange will always be ample to take compression, and the part in compression will be but a small portion of the depth of the slab, that is to say, the extent of the compression will be less than the depth of the slab, so that we are able to calculate as though a T-beam were a simple rectangular beam, and the foregoing diagrams for rectangular sections apply to tee beams in practice. So far the formulæ are simple, and at the same time it is contended they are more accurate than the usual.

DOUBLY REINFORCED BEAMS.

Now, what is to be said as regards sections reinforced in compression ? Space forbids much being said on doubly reinforced beams. The author's method is to make sure that the compression steel cannot buckle outwards by providing proper anchors and then to determine the moment of resistance for such steel, as though it were a steel beam, taking its arm as the distance between the top and bottom reinforcement, and add that to the moment of resistance taken by the concrete. Adding the total compression in the concrete to the total compression in the steel, we get a grand total which, divided by the permissible stress, gives the amount of tensile steel to be provided.

There may be convenient opportunity later to go more into detail on this subject.

PILLARS.

We are led next to the question of the strength of reinforced concrete members subjected to simple compression as, for instance, short pillars. Here again the modular ratio comes into customary calculations. Of recent years, however, doubts have been thrown upon the adequacy of such theory, more particularly in America, where attention has been drawn to the fact that concrete when hardening undergoes contraction, this continuing for a long period of time. This contraction induces a longitudinal shortening in the steel, and may induce so much strain therein that the stress can actually reach the yield point of the steel. That, however, can only apply in the case of a moderate quantity of steel. If a very great quantity of steel be provided, and there be little or no load on the pillar, the concrete would try to diminish the length of the steel bars in contracting, but the steel would be strong enough to hold firmly, with the result that it would crack the concrete, which would be put in tension. The steel would, of course, have suffered a small compression due to the contraction of the pieces of concrete that were still uncracked, so far as adhesion would permit, but such adhesion would be largely destroyed. If now a load be applied, the steel would undergo further compression, and the cracks would be closed. Still further loading would begin to put compression into the concrete which was originally under tension, owing to the steel trying to snap the concrete. In a pillar or beam that is not so heavily reinforced the same argument applies—the contraction of the concrete tends to put compression into the steel, and the steel in turn tends to put tension in the concrete. The load that is taken on the steel must come off the concrete. Therefore, though the steel may be stressed to the yield point the ability of the concrete and steel as a combination will be just the same as if no contraction had taken place, because the initial compression in the steel resulting from the contraction is only causing initial tension, as one might say, in the concrete which has to be taken out subsequently before we can reach the ordinary compressive resistance of the concrete. Naturally, such contraction of the concrete upsets any ideas we may have about the stresses in the concrete and steel being proportionate to the ratio of their moduli of elasticity. So long as adequate precautions are taken to prevent buckling of the steel we can calculate the resistance quite simply without having anything to do with the modular ratio, and consider it merely as made up by the concrete being able to withstand as much as it would if it were plain concrete and the steel as much as a short steel pillar. The addition of the two will be the total resistance of the reinforced concrete pillar. That is, supposing the steel has an ultimate compressive resistance of 55,000 lb./in.², and the concrete 2,000 lb./in.², and that the pillar contains 100 sq. in. of concrete and 2 sq. in. of steel, the total load that the pillar will carry is 200,000 lb. plus 110,cco lb. = 310,000 lb. The reinforcing rods being compressd naturally tend to buckle, and the ability to develop the ultimate strength all depends on adequately restraining the rods from buckling. *Fig.* 31 shows by dotted lines the form that such buckling would take. The links tying these vertical rods together are indicated. If the steel rods and links formed an open structure without any concrete in the middle the rods could buckle inwards, but as it is they are forced, if they are to buckle at all, to go outwards. Years ago the author adopted a standard spacing of links with the object of ensuring that at ultimate rupture the steel could be stressed to its maximum compressive resistance without being liable to buckle as a slender strut. The following gives the calculation for maximum permissible spacing :—

Fig. 31 shows a portion of a reinforced concrete pillar, the rods of which are retained by links from bursting outwards, the spacing of which should not exceed 16 times the diameter of the rods if the maximum stress is to be developed therein. W. Alexander's *Columns and Struts* provides precise but practical data for determining the forces developed in latticing of steel pillars, and we may adapt his method to the present case. The links will evidently have to carry the forces that would be developed at the two bearings of pin-ended struts. A portion, so considered, is shown enlarged in *Fig.* 32.

$$\text{Then } F = \frac{s}{\cos a} = \frac{P \sin a}{\cos a} = \frac{P \sin a}{\sqrt{1 - \sin^2 a}} = \frac{Pv}{\sqrt{K^2 - v^2}} = \frac{Pv}{K} \text{ approx.}$$

Therefore force to be developed in a length $16d$

$$= \frac{2Pv}{K} = \frac{2}{n}\sqrt{\frac{PI}{E}}\left(f_{max} - f_d\right)$$

Taking values of a reduced direct stress in rods $f_d = 40{,}000$ lb./in.² and a maximum stress (combined bending and direct stress) $f_{max} = 60{,}000$ lb./in.² we get $P = 40{,}000\,\frac{\pi d^2}{4}$, $I = \frac{\pi d^4}{64}$, $n = \frac{d}{2}$, $E = 30{,}000{,}000$. Inserting in the formula

$$\text{Force to be developed} = \sqrt{\frac{440{,}000\pi^2 d^2}{d4 \times 64 \times 30{,}000{,}000}}(60{,}000 - 40{,}000)$$

$$= \frac{10{,}000\,\pi d^2}{\sqrt{3{,}000}} = 573d^2 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Calling the pitch of the links p

the number of links $n = \frac{16d}{p}$.

An initial stress will be put in the links by lateral swelling of the concrete under the longitudinal compression. Taking Poisson's ratio as $\frac{1}{4}$ and the maximum longitudinal shortening as $\frac{1}{400}$ we ascertain the initial stress to be $\frac{1}{400} \times \frac{1}{4} \times 30{,}000{,}000 = 18{,}750$ lb./in². Assuming that we limit the stress in links to the yield point of mild steel, say 40,000 lb./in², the maximum stress that can be put in any link will be 21,250 lb./in².

Therefore the resistance of each link will be

$$21{,}250\,\frac{\pi\,\delta^2}{4}$$

$$\text{and of } n \text{ links} = 21{,}250\,\frac{\pi\,\delta^2}{4}\,.\,16d = 267{,}000\,\frac{\delta^2 d}{p} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Equating (1) and (2)

$$573d^2 = 267{,}000\,\frac{\delta^2 d}{p}$$

$$p = 466\,\frac{\delta^2}{d}$$

For a $\frac{3}{16}$ inch diameter round link $p = \frac{16 \cdot 4}{d}$

For the smaller bars $16d$ will be the limit, so that we get the pitch for different sizes of bars, say: $\frac{1}{2}\phi$ 8 in., $\frac{5}{8}\phi$ 10 in., $\frac{3}{4}\phi$ 12 in., 1ϕ 16 in., $1\frac{1}{4}\phi$ 13 in., $1\frac{1}{2}\phi$ 11 in., $1\frac{3}{4}\phi$ 9 in., 2ϕ 8 in. The author adopts as a standard 8 in. throughout up to 2 in. diameter rounds.

It will be seen that the links are merely employed to restrain the rods from buckling and are not for the purpose of strengthening the concrete by hoop tension.

There is altogether insufficient experimental data regarding what happens in testing slender reinforced concrete pillars to destruction to be able to give a fully rational method of calculating such members. In view of this it is best not to employ slender pillars, which can be done by keeping down the unsupported length. We must, however, deal with the cases of combined bending and compression in struts, as also compressive reinforcement in members subjected to bending alone. This paper is already too long elaborately to treat the subject. Those who are competent to calculate combined thrust and bending will be quite able to adjust the author's methods, if they approve of them, to the problem. Some opportunity may present itself later for the author to publish his detailed views on this subject.

It may be as well, however, here to refer generally to the matter of monolithic construction where the beams and pillars are rigidly coupled together. Bending in the beams induces bending in the pillars, and *vice versa*. There has been a good deal written on the subject in recent years about most interesting and valuable investigations to show what great bending strains may be induced in pillars by the bending of either steel or reinforced concrete beams connected thereto. Determination of the bending moments and shearing forces in the various parts is computed by two mathematical methods, one being to consider the change of slope of the axis of such members when deformed by bending, and the other to employ the theorem of least work. Such essays serve an excellent purpose. The only question the author wants to raise is as to the conclusions that are to be drawn from such investigations. Too frequently these seem to be that previous methods of designing pillars are all wrong. The bending moment on pillars is treated as being equivalent to applying the direct load eccentrically. Eccentric loading when the eccentricity is actual, as, for instance, a load suspended or lodged on a bracket on the side of a pillar, is very different from an equivalent eccentricity of that kind from a practical point of view.

Some of the essayists have suggested that provision must always be made fully to resist the stresses calculated to be due to such equivalent eccentricity, and if one were to follow just what they say we should have to conclude that a very great number of structures have been erected that must be in imminent danger of collapse, and more than that, they ought to have collapsed. Seeing that they have not makes one desire to find the explanation. At the expense of being considered trite, I would like to remind the exponents of these newer methods that theories should endeavour to explain the facts. The author's view is that the explanation of why pillars could be calculated in the past merely for the direct load, and designers practically ignore the bending effects induced by a beam rigidly coupled thereto, and no danger resulted, is merely that plastic deformation came in to assist. Take, for example, a simple portal, consisting of just two pillars sustaining a beam at the top. If the beam were connected to the pillars and the beams happened to be rather shallow, and the pillars rather short and stumpy, the pillars would endeavour to restrain the ends of the beam, with the result that the bending would tend to cause big bending moments in the ends of the beam and the tops of the pillars. Now, if the pillars were not able to sustain such bending moments, they in turn would be bent. As soon as they bent, however, the fixity at the end of the beam would partly give way, and the beam would have to develop more of the curvature it would have had if it had been simply supported. The stresses induced in the pillars would be sufficient to exceed the yield point, and the metal would stretch. But as soon as the pillars had been bent, and the beam took more of the ordinary curvature of a simply supported beam, there would be no longer the big bending moment put in to the pillars. The two tendencies will naturally give some intermediate value between, that is, the pillars will take as much bending as they can, and the beam will have to take the rest. The bending of the pillar creates an actual eccentricity, but a very small amount. The plastic deformation, therefore, is the means of securing safety in such a case.

Factors of Safety.

Euler and succeeding mathematicians who developed the theory of elasticity, strangely enough, never devised a mode of computation whereby working stresses in slender pillars can be estimated. They merely tell us the moment at which a pillar will fail, and leave us to obtain the safe working load by dividing the ultimate load by a factor of safety. Only in regard to beam design have engineers changed over from the earlier practice of computing ultimate strengths and adopting factors of safety thereon. Seeing how far astray those engineers can wander whose minds are concentrated on trying to calculate working stresses the author prefers to revert to the procedure of some generations of eminent engineers of the past, who based their practice upon experience and upon experiments made under practical conditions on full-sized or model members, and did not depend so much upon mathematical theorising about ideally elastic materials, and elaborate experiments that did not conform to practical conditions.

[We hope to give a report of the discussion on this paper in our next issue.]

MEMORANDA.

Professional Announcements.

Mr. Gower Pimm, A.M.Inst.C.E., reinforced concrete engineer, informs us that he has opened an office at No. 72, Queen Square, Bristol.

Mr. R. N. Stroyer, B.Sc., M.I.M.E., has started practice as consulting engineer at 4, Westminster Palace Gardens, Victoria Street, S.W.1. Mr. Stroyer, who has had considerable practical experience as chief engineer and designer for twelve years to Messrs. Christiani & Nielsen, and Messrs. Somerville, proposes to deal with all branches of reinforced concrete, more particularly sea and river works.

Concrete Testing Machine at Armstrong College.

A new testing machine for compression and bending is being installed in the Engineering Laboratory at Armstrong College, Newcastle-on-Tyne. This machine, which is claimed to be the first of its kind, is capable of dealing with columns 10 ft. in length and beams of 9 ft. span, with a maximum width of 4 ft. Owing to its width it will be possible to test broad flange or T beams as used in reinforced concrete construction. The maximum load of 120,000 pounds is obtained by hydraulic power; and the measurement of the load is made by means of multi levers in conjunction with the ordinary steelyard, which is graduated to read in steps of 25 lb. The machine was constructed by Messrs. W. T. Avery & Co., to the College specifications.

Iron and Cement Paving.

The Société Anonyme des Hauts Fourneaux et Fonderies de Pont-à-Mousson is at present carrying out at the Strasbourg-Cronenbourg goods station an application of its patented system of cast-iron and cement paving. This new process consists in arranging, on a thin concrete course, cast-iron sections enveloped in a plentiful bed of Portland cement in such a way that they lie level with the surface. The unconnected cast-iron sections are arranged in a special manner, their distance apart being inversely proportional to the resistance required. This type of roadway is claimed to be indestructible, to produce neither dirt nor dust, and to cost practically nothing for upkeep. Its cost price is, in general, stated to be below that of pavings at present employed.

Concrete on the Lincoln Highway.

A publication of the Atlantic City Chamber of Commerce gives particulars regarding the Lincoln Highway, the longest road in America, which stretches across the continent for a distance of 3,300 miles. The Chamber of Commerce is emphatic in its opinion that the cheapest type of road is the all-concrete road, on account of the saving it shows on all other types—the saving, of course, not being reckoned on the first cost but on the total of initial cost and maintenance costs over a term of years, which is the only method by which the cost of a road can be ascertained. So far some 490 miles of this road have been constructed of concrete, but many sections already laid with other materials are being converted to concrete. In Pennsylvania, for instance, a length of 320 miles between Philadelphia and Pittsburgh is being rebuilt in concrete owing to the excessive maintenance cost of the macadam surface; the maintenance of the macadam road cost on an average 2,333 dollars per mile, whilst the new concrete road is not expected to cost more than 200 dollars a mile for upkeep. In conclusion, the Lincoln Highway Association states: "From its study of highway costs and annual maintenance charges on all types of construction along the Lincoln Way for the past nine years, the Association is to-day more than ever convinced of the correctness of its policy, adopted in 1913, of advocating concrete construction where practicable on the Lincoln Highway as being the cheapest in the long run. Looking ahead now, it is possible to visualise the ultimate ideal of a permanent concrete highway, extending from the foot of 42nd Street to Lincoln Park, San Francisco."

Concrete Lamp Standards and Shock.

The utility of reinforced concrete as a material for the construction of lamp standards was exemplified in a remarkable way the other day. A heavy motor lorry collided with a standard of this type with the result that while the post was bent it was not damaged to any serious extent, and even the gas pipe remained intact. If the standard had been of cast iron it would have been shattered.—*Municipal Engineering.*

PROSPECTIVE NEW CONCRETE WORK.

BENFLEET. — *Bridge.* — The Rochford R.D.C. has under consideration the erection of a bridge over Benfleet Creek to connect Canvey Island with the mainland.

BIRMINGHAM.—*Gas Works.*—The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £400,000 for extensions in connection with the gas undertaking.

BURTON-ON-TRENT.—*Gas Works.* — The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £8,500 in connection with the gas undertaking.

CARLOGGAS.—*Reservoir.*—The St. Austell R.D.C. has decided to construct a new reservoir, with a capacity of 500,000 gallons, at a cost of £11,864.

CHELMSFORD.—*Road.*—The Ministry of Transport has offered the T.C. half the estimated cost of £36,000 for the construction of a new road from Springfield Road to Duke Street.

COLWYN BAY.—*Gasworks.*—The Finance Committee of the U.D.C. has decided to apply for sanction to borrow £40,860 for gasworks extensions.

ENFIELD.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application of the Enfield U.D.C. for sanction to a loan for sewage disposal works. It is estimated the additional works will cost £75,000.

GILDERSOME.—*Sewage Works.*—The Ministry of Health has given its sanction to the U.D.C. to carry out a sewage disposal scheme.

GLASGOW.—*Bridge.*—At a meeting of the Corporation Statute Labour Committee, a minute recommending the Corporation of Glasgow to construct the proposed bridge over the Clyde at Oswald Street mainly of ferro-concrete was discussed, and it was decided that five members of the Committee, together with the proper officials, be appointed to inspect the ferro-concrete bridges at Warrington, and elsewhere in England, as well as similar bridges in Paris and neighbourhood.

HOLMFORTH.—*Sewage Works.*—The U.D.C. has decided to apply to the Ministry of Health for sanction to borrow £20,000 in connection with the sewage outfall works.

HORSFORTH.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the U.D.C. to borrow £950 for sewage disposal works.

HUNTINGDON.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Cannock U.D.C. for sanction to borrow £7,000 for sewerage and sewage disposal works.

ILKLEY.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £7,000 for extensions and improvements to the sewage disposal works.

LIVERPOOL.—*Dock.*—The Mersey Dock and Harbour Board has authorised its engineer to arrange for the enclosing of the Gladstone Graving Dock, at an estimated total cost of £408,569.

LOUGHBOROUGH.—*Gasworks.*—The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £8,879 for works in connection with the gas undertaking.

MANCHESTER.—*Road.*—The Corporation Town Planning Committee has received sanction to borrow £106,851 for the construction of a new road from Moston Lane to Rochdale Road.

SHEFFIELD.—*New Road.*—The Ministry of Transport has agreed to provide half the cost of the total £80,000 for the construction of a new road at Sheffield.

TORQUAY.—*Promenade.*—The Corporation has under consideration the construction of a promenade, the provision of pleasure grounds, and the filling-in of the inner harbour, at an estimated cost of £28,000.

WAKEFIELD.—*Sewage Works.*—The Ministry of Health has held an inquiry into the Corporation's application for sanction to borrow £88,000 for improving the sewage disposal works at Calder Vale.

WICKERSLEY.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Rotherham R.D.C. for sanction to borrow £14,249 in connection with the sewerage and sewage disposal works for Wickersley and Dalton parishes.

TENDERS ACCEPTED.

ABERDEEN. — *Bridge.* — The Corporation Links and Parks Committee has accepted the offer of Messrs. James Scott (Aberdeen), Ltd., to construct a reinforced concrete bridge at Corf House Gap, at a cost of £3,447 13*s.* 6*d.*

BLYTH.—*Quay Wall.*—The Harbour Commissioners have accepted the tender of Messrs. R. McAlpine & Sons, at between £13,000 and £14,000, for the construction of a reinforced concrete quay wall at the Import Dock in the South Harbour.

LONDON.—*Concrete Floor.*—The London County Council has accepted the tender of Messrs. Garrett & Son, of Balham Hill, S.W., at £12,398, for the construction of a concrete floor at the central tramway repair depot.

NEEDHAM MARKET.—*Bridge.*—The East Suffolk County Council has accepted the tender of Messrs. G. Munday & Sons, Ltd., Botolph Lane, Eastcheap, E.C., at £787 for the reconstruction in reinforced concrete of Needham Market bridge.

STOCKTON-ON-TEES.—The T.C. has accepted the tender, at £2,093 11*s.* 8*d.*, of Messrs. T. A. Davies & Co., South Shields, for the construction of a reinforced concrete pipe sewer.

NEW COMPANIES REGISTERED.

Carter Construction Co., Ltd. (180,366). Registered March 16. Manufacturers and workers in cement, lime, plaster, etc. Nominal capital, £2,000 in 2,000 £1 ordinary shares. Directors to be appointed by subscribers; qualification of Directors, £100; remuneration of directors, to be voted by Company. Subscribers: B. H. Dobbs, 20, Stoney Street, Nottingham; A. H. Thaves, 11, High Street, Nottingham; E. G. Powell, 16, George Avenue, Long Eaton; W. Goulding, 49, Burton Street, Nottingham.

Monnoyer British Construction Co., Ltd. (180,552). Registered March 23. 6, New Burlington Street, W. Builders and general and public works contractors. Nominal capital, £10,000 in 10,000 £1 shares. Directors: A. Monnoyer, 178, Avenue de Longchamp, Brussels; M. Monnoyer, 235, Avenue Moliere, Brussels; E. Fricers, 60, Rue Stanley, Brussels; J. A. Eshelby, 27, Lancaster Gate, W. Remuneration of directors, £50 each; chairman, £100.

Silence Concrete Sleeper Syndicate, Ltd. (180,558). Registered March 23. Manufacturers of cement and concrete sleepers. Nominal capital, £100 in 100 £1 shares. Directors to be appointed. Qualification of directors, 1 share; remuneration to be voted by Company. Subscribers: W. Lennard, 3, Love Lane, E.C.3.; R. C. Radeglia, 87, Glenwood Avenue, Westcliff-on-Sea.

Simplex Expanded Metal, Ltd. (180,601). Registered March 24. Contractors, builders and engineers in concrete construction. Nominal capital, £2,000 in 2,000 £1 shares. Qualification of directors, 1 share; remuneration to be voted by Company. Directors to be appointed by subscribers. Subscribers: N. J. Dell, 68, Gloucester Terrace, N.W., and H. E. Warner, 1, Great Winchester Street, E.C.

Bateman's Concrete Works, Ltd. (181,066). Registered April 11. 102, Victoria Street, S.W.1. Manufacturers of concrete. Nominal capital, £4,000 in 4,000 £1 shares. Directors: F. Bateman, 21, Holland Park Road, W. 14; and W. P. Morgan, 47, Station Road, Sidcup. Qualification of directors, £500; remuneration, £50 each.

"Try" Concrete Slab & Partition Co., Ltd. (181,112). Registered April 12. 6 and 7, Cumberland Market, N.W.1. Manufacturers of blocks, slabs, partitions, bricks and artificial stone. Nominal capital, £1,000 in 200 1*s*. deferred shares and 990 £1 shares. Directors: H. W. Try, 30, Holmdale Road, N.W.6; A. J. Russell, 40, Orchard Road, Kingston-on-Thames; F. Howling, 5, Hilldrop Crescent, N.W.7. Qualification of Directors, £25.

TRADE NOTICES.

Mr. G. W. Cosby, Northern District Office Manager of the Westinghouse Morse Chain Co., Ltd., has joined Messrs. Jenks Bros., Ltd., of Wolverhampton, who have been appointed sole agents for Yorkshire for the Westinghouse Morse inverted tooth rocker-joint chain drives manufactured by The Westinghouse Morse Chain Co., Ltd., at Letchworth. Mr. Cosby will thus retain his full interest in the sale and installation of Westinghouse Morse rocker-joint chain drives. Mr. Cosby will still be located at Leeds, for the time being at Standard Buildings, City Square.

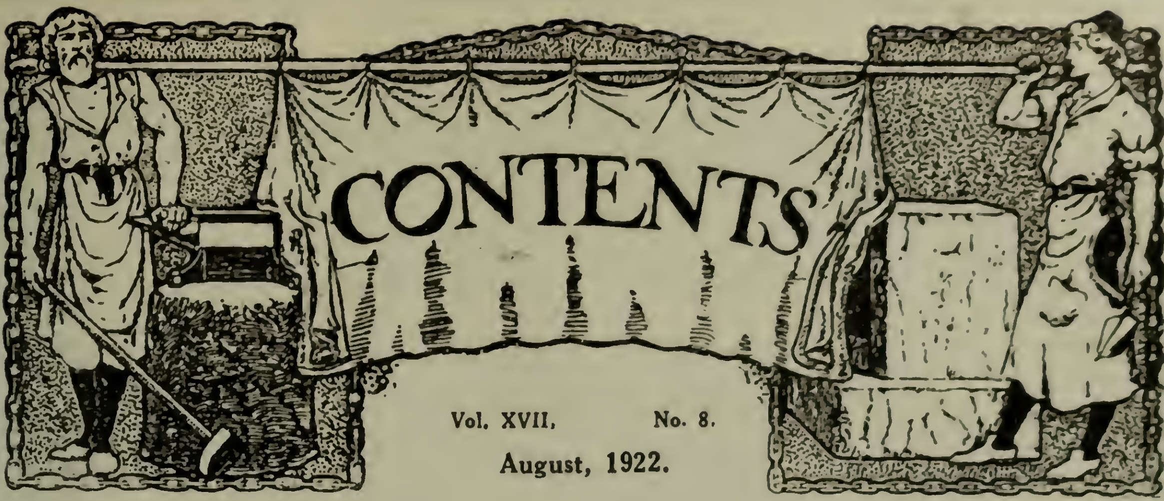
A well-produced volume issued by Messrs. L. G. Mouchel & Partners, of 83, Victoria Street, S.W. (*Mouchel Hennebique Ferro-Concrete*, price 21*s*. net) shows the varied uses to which "Hennebique" ferro-concrete has been applied in this country during the past quarter of a century. Part I contains a general description of the principles underlying ferro-concrete construction and the distinctive features of the "Hennebique" system, as well as of the hollow piles, cylinder piers, pre-cast bracings, and hollow flooring introduced by the firm. This part also deals with various characteristics of ferro-concrete construction, as, for instance, rapidity of execution, durability, watertightness, hardness, strength and cohesion, and resistance to shock, vibration, and fire. Part II is devoted to illustrations and brief descriptions of different classes of structures, grouped in some twenty sections, and including buildings of all kinds, bridges, marine and river works, aqueducts, water reservoirs and towers, sewage disposal tanks and works, coal, stone and ore bunkers, and miscellaneous structures. The volume is very completely indexed.

At the Royal Show, Cambridge, Messrs. Mann's Patent Steam Cart and Wagon Co., Ltd., of Hunslet, Leeds, will have on view, by permission of the owners, Messrs. W. J. Lobjoit & Son, Ltd., the well-known market gardeners, a Mann patent steam wagon, fitted with a special type of body for Covent Garden market work. This is the third wagon Messrs. Mann's have supplied to Messrs. W. J. Lobjoit & Son, Ltd.

[*Mr. J. G. West, M.B.E. (H.M. Office of Works), Architect.*

THE NEW PENSIONS BUILDING AT ACTON.

(*See page* 505.)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CONCRETE AND CONSTRUCTIONAL ENGINEERING

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EDITORIAL NOTES.

CONDITIONS OF CONTRACT.

WE are glad to learn that the negotiations between the Royal Institute of British Architects, the Surveyors' Institution, the Society of Architects, the National Federation of Building Trades' Employers, and the Institute of Builders, which have been proceeding for some time with a view to the preparation of a Standard Form of Contract for building operations, have reached their final stage. A conference of representatives from these bodies has appointed a Drafting Committee, which is at work on the Contract Document. All matters on which the parties fail to reach agreement will be referred to arbitration by a Tribunal of Appeal, consisting of one representative each of the builders and the architects, under the Chairmanship of Sir William Mackenzie, K.C. (President of the Industrial Court), whose appointment was made with the consent of the Ministry of Labour. These negotiations have now been proceeding for such a long time that it may reasonably be expected that all the interests of the different parties have been thoroughly sifted, and the work of the drafting committee should not be a protracted one. An agreed form of building code for the whole of the country which will be fair to the building owner, architect, builder, and all concerned will be a boon to the industry and the public, and disentangle much of the present confusion. The fact that the Appeal Tribunal consists of three only is a welcome feature, for it is the general experience that the smaller such a body is in numbers the quicker will its decisions be arrived at.

INSPECTORS OF CONCRETE WORK.

THE importance which in America is attached to what is one of the first essentials if concrete work is to be entirely satisfactory—skilled and thorough supervision —is shown by a report of the American Society for Testing Materials which has just reached us. This report embodies a proposed set of rules for the inspection of concrete work, and contains the following emphatic remarks : " A grave responsibility rests on the inspector. The success of the construction may hinge on the proper performance of what may appear to be minor features of the work. In case of careless or faulty construction which results in loss of life the inspector may be charged with criminal negligence. . . . The inspector should have practical experience and an understanding of the fundamental engineering principles involved in the construction to which he is assigned ; he preferably should have had technical training. The inspector should keep abreast of developments by reading the engineering and trade press, books and monographs on the subject, and by attendance at meetings at which concrete work is discussed. Concrete and reinforced concrete construction is a rapidly-developing art and it is imperative that the inspector should be informed as to the most recent improvements, if he is to handle his work intelligently and efficiently." The suggested rules fully outline the duties of an inspector of concrete, and appear to be so comprehensive as to leave no loophole for any bad or indifferent work being passed, or of the design and specification not being accurately followed, if they be conscientiously followed. The Concrete Institute has published a pamphlet embodying similar suggestions for the guidance of inspectors in this country, but what is undoubtedly of the first importance here is the provision of further educational facilities—both theoretical and practical—for such men if the much larger number of inspectors which are certain to be required in the near future are to be adequately equipped properly to carry these rules into effect. The formation of a central bureau from which inspectors may be obtained with an assurance that they will be efficient is also worthy of serious consideration ; and, if the organisation of such a service be outside the scope of the Concrete Institute, it might be consummated by the inspectors themselves on the lines of the Clerks of Works' Association, which in addition to providing a means of social intercourse between its members keeps a register of proficient clerks of works whose services are available to architects.

CONCRETE IN SEA WATER.

THE use of reinforced concrete in sea water is subject to certain dangers except where special precautions are taken. It is interesting, therefore, to note that a five-mile boulevard 52 ft. wide, including a length of 9,000 ft. carried across sea-water channels by a reinforced concrete trestle construction resting on concrete piles, is about to be constructed in New York.

The danger of corrosion appears to have been carefully considered, and the precautions proposed to be taken in the design and specification resolve themselves chiefly into the following :—

(1) The use of a very rich mixture.
(2) Careful grading to obtain maximum density.
(3) The use only of the best graded materials of their respective kinds.
(4) The rounding of all exposed corners.
(5) The provision of much more cover than is customary.

Subject to special tests in regard to strength, grading, etc., the concrete in piles, beams, and girders is to be mixed in the proportion of one part cement, one part sand, and two parts trap rock, while the concrete in the abutments and deck of the trestle is to be mixed in the proportion of one part cement, one part sand, and three parts trap rock or gravel. It will be seen that this is very much richer than the customary proportions. As regards the covering of concrete, this is to be 3 in. in the case of piles, and their corners are to be rounded to a 2-in. radius. The portion of the pile between low-water and high-water is to be sheathed in timber 3 in. thick, provided with a bituminous lining, the object of this being not only to prevent immediate contact of the water with the face of the concrete, but also to guard the protected parts of the pile from abrasion due to floating ice or débris. The piles are to be hardened or seasoned for at least sixty days before being driven, so as to make them still more resistant to sea water.

The crushing strength of the concrete is required to be 3,000 lb. per square inch in cylinders at the age of twenty-eight days, and the wetness of the concrete is to be controlled by means of a slump test. The test consists in filling moulds 8 in. in diameter and 16 in. long with newly-mixed concrete, lifting away the mould, and ascertaining how much the upper surface sinks by spreading of the concrete; this test is to be made at least once a day before starting work, and whenever new material is brought to the work or after a change of atmospheric conditions, and the slump is then to be the same as in tests made by the engineers on concrete of such a consistency as they consider suitable. The concrete piles are 24 in. square, and 6 ft. 7½ in. apart in the trestles, the trestles themselves being 24 ft. centres. The work is, of course, provided with expansion joints, the ends of the free beams resting on cast-iron rollers and plates.

EDUCATION AND SCHOOL BUILDINGS.

To state that all human progress is a direct result of education and research is but to reiterate what has been often said before, and what is obvious to all; at a time, however, when retrenchment wherever possible is necessary, and when education is being subjected to the "axe" in common with other avenues of national expenditure, it is essential that the relative importance to the national well-being of the various items on which money is to be saved should be borne in mind by those in authority. If the war and its aftermath taught us anything at all it is that a highly-skilled race is indispensable if this country is to maintain its position in the world, and it is from many points of view regrettable to see that the facilities for education are being encroached upon on the plea of economy. We have no concern here with politics, but it may be pointed out that there are true economies and false economies, and surely any saving effected by cutting at the roots of the tree on which the prosperity of the nation depends so vitally comes within the latter category? The war-time restrictions on building and the large amount of school building now being postponed on the ground of cost must, however, inevitably mean that in the near future a very considerable number of new school buildings will be erected, and it is with this aspect of the question that we are more concerned. In this issue we give some illustrations of typical American school buildings, erected in concrete, which from the architectural point of view are as fine as anything built in other materials, and thoroughly demonstrate the suitability of concrete for this type of building. The use of concrete for the columns in the single-story buildings is particularly interesting, as there is a marked inclination in the direction of one-story schools which can be easily converted into practically open-air schools by opening the very wide windows, and which the scholars may leave to take their lessons in the grounds without having to use several flights of stairs. In case of fire, too, this type of school has much to commend it in the rapidity with which it can be emptied, and in the absence of staircases. There are already indications that some of this much-delayed work is about to be put in hand, and it is interesting to note, and perhaps a sign of the materials to be used, that one of the largest municipalities in the country—Manchester—recently signified its intention of inquiring, through its Education Committee, into "the suitability of concrete for school buildings." Perhaps our illustrations will go some way towards answering the question.

CONCRETE LININGS AND CANAL MAINTENANCE COSTS.

THE very considerable economy which can be effected in the cost of supplying water for irrigation purposes by lining canals with concrete is shown by the experience of the United States Reclamation Service on the Orland irrigation works, where a saving of 60 per cent. has been made by the use of a concrete lining 1½ in. thick. Some 64 miles of canals on this system have now been lined, and the records kept show that the upkeep charges for earth and concrete-lined sections are 53·70 dollars and 19·50 dollars a mile respectively. The loss of water by seepage is practically eliminated by the concrete lining, and this, in times of shortage of water, is as important, if not more important, than the question of cost, although the saving effected by lining is so great as rapidly to repay the initial cost. The question is not, perhaps, so important in this country as in America, owing to the relatively small amount of such works here, but the experience in the United States should be useful to British engineers carrying out irrigation works abroad.

SOME THOUGHTS ABOUT CONCRETE.

By REGINALD HALLWARD.

It is only necessary to look at the photographs in the June issue of this Journal, in which the viaduct and bridges at Dover were illustrated, to see that such construction does not form such a wound in the countryside as a skeleton iron or steel bridge. It clothes its structure with a character more compatible with the countryside, and nature and the hills are not contradicted by the stark character of the bridge. There is nothing which rests more on old prejudices than that belief which assumes that concrete cannot be used externally when the appearance of the building is important. I think this notion of its unpleasant surface dates from the time when very cheap work was done in concrete, the material mixed coarsely, and showing the marks of the shuttering in an unsightly way. But it is wonderful how old prejudices cling, and what has no necessary application to the material, its unpleasant surface, is brought as an objection to its use.

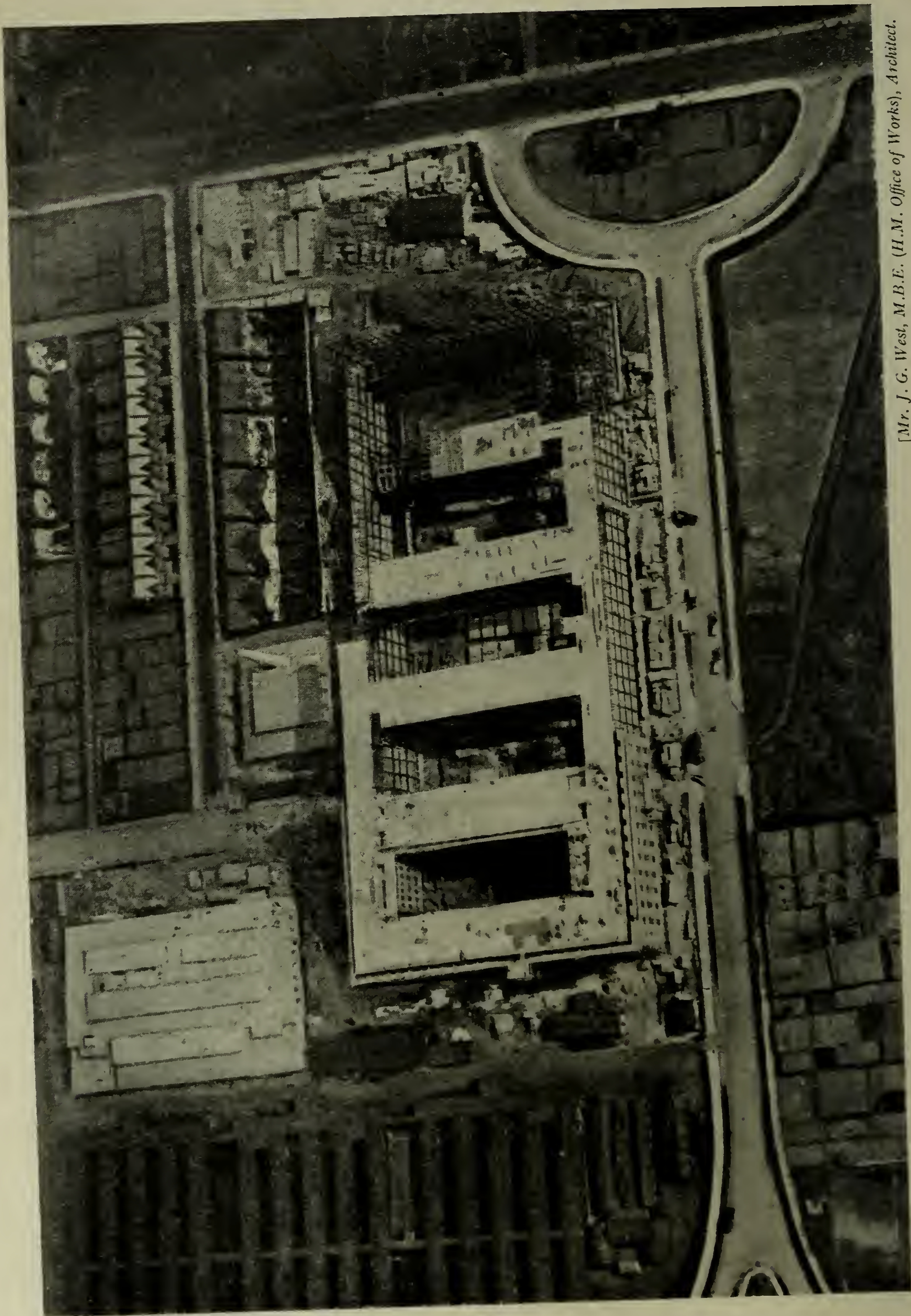
I have suggested in a sketch which illustrates this article a plan for a church, or, for that matter, it would adapt itself equally for a market hall, with the market on the ground floor and the upper part devoted to municipal or other offices, in which the aim is to show a very simple treatment, avoiding, as much as human weakness enables one, unnecessary mouldings and embellishments. The chief decorative feature is reached in the brown facings at the corners of the walls. This pattern of brown running up the sides would be less sharp in contrast than if black or grey blocks were used for the purpose, and would contrast very pleasantly with the limewash of the rest of the building. The building is planned with much simplicity as suggesting the possibility of agreeable results without extra expense. The entrance to the church is reached from the top of a flight of steps, and the ground floor below would be for meetings and entertainments. The idea of the form for the building was gained from a recollection of the Market Hall at Keswick. This quaint and Continental looking building, which stands in the centre of the town and is by far the most characteristic building in it, seems to anticipate in its character a material like concrete, and might almost have been built with it. I have in mind in suggesting such a treatment the possibility of getting free from all the imitative forms which are supposed to be necessary in an ecclesiastical building, and by so doing to restore more of the spirit of ancient worship. All the artificialities of pseudo-Gothic detail seem only to obstruct the religious purpose and to thwart what it is supposed to assist. Concrete is perhaps the best material, because freest from precedents, wherewith to recover a more genuine and robust character in work of the kind. What we need is to approach our work directly : not through a thousand precedents or formulæ of how such a building should be planned, but on the reality of our wants. If we approach our work in this way it will not be long before all the old stock-in-trade of derivative and borrowed character will be replaced by something really native and vital, because we shall be expressing ourselves again. And then we shall find that the vast differences between art and life will have disappeared, and that what we build for use, with little thought of anything self-conscious about art, will be true art after all.

As a writer in this journal pointed out, " artistry need not necessarily be costly." The supposed identity between expense and art is far from being true, though the unfortunate client who had all sorts of expenditure thrust upon him in the name of architecture, during the late Victorian period particularly, may be excused for thinking so. But the idea has grown through a wrong way of thinking about art. The relation of art to industry, whether building or anything else, is something native and growing through it, not artificially imposed upon it afterwards. It is sometimes assumed that all the possible forms and combinations, as also the kind of ornament that is available, have already been reached, but though in one sense there is nothing new under the sun, these combinations are capable of endless transformation and new interpretation, and, like the notes of a musical instrument, lend themselves to endless new combinations and themes only limited by the amount of freedom and endowment in the mind to create them. Imitation of other materials, rustication, and so on, should be avoided, because they suggest that concrete is not in itself able to create its own forms, or to reach satisfactory results unless masquerading in other materials. This is far from being the case, and it also deters the proper effort to get from concrete its own qualities. At the same time we must not draw the line too hard or be bound by theories, even though in their general application they assist us so much. I see no objection to the facings in reveal at the corners of the Pensions Building at Acton, because they suggest a massive character of support to the corners as of stone. On the other hand, the lining out of the sand-blown wall surfaces on the corridors at Drury Lane Theatre to represent large blocks of stone has a very mechanical and unsatisfactory character—it *looks* sham, as well as being so. There are, however, cases in which considerations of appearance may suitably govern constructional needs, as in the gable roof instead of the flat one. If it is the case that the flat roof is that to which reinforced concrete best lends itself, it is no less the case with a house than with a bridge that these constructional considerations may be suitably modified for the sake of appearance.

In these days of recovery, values declare themselves quite evidently, because in a period of difficulty and reconstruction they are more likely to do so. There is little place now for that undesirable redundancy which has accustomed us in our building to so many foreign, antiquated, and derived forms and ornamental details. The good architect will find his opportunities through this changed spirit, which will liberate his work in many ways. While we should, of course, aim to give permanence to our buildings, we may at the same time become a little too self-conscious over the business. It may be that our time is not one when the most permanent contributions can be made to architecture, that a humbler spirit than that which assumes the immortality of its building becomes the art. If we get back to service, our real needs, outside of the vicious circle of personal ambitions, and the desire to impress ourselves, so that we are less entangled in our own identity and absorbed more into the common life—in this closer, less-assuming, relationship and understanding of our fellows and our own claims we may build for use in such a way that it is again touched directly with the human spirit. For all the heights of art mean little more than this at their best: that the individual speaks, or builds, or in whatever way he works, through the race. In the re-shaping of life to this more democratic ideal we have a vehicle in concrete through which to work, if its use is developed in the best ways.

The afternoon on which I visited the new Pensions Building at Acton, I saw a partially-completed church some little way beyond. It was all furnished in the accustomed manner, but it pre-supposed all sorts of requirements for a church that are not its essential requirements at all—that it must be Gothic; must be ornamental; that a building to be religious must dress up and pretend to be that from which it is in fact a thousand miles away. On coming out and looking once more at the Pensions Building I felt relief such as a man experiences when he has recovered his independence, and can respect himself again. The building at any rate included no shams, and what there was of it was itself, very inarticulate but with its feet on the ground!

Suggestion for a Church or Market Hall in Concrete.



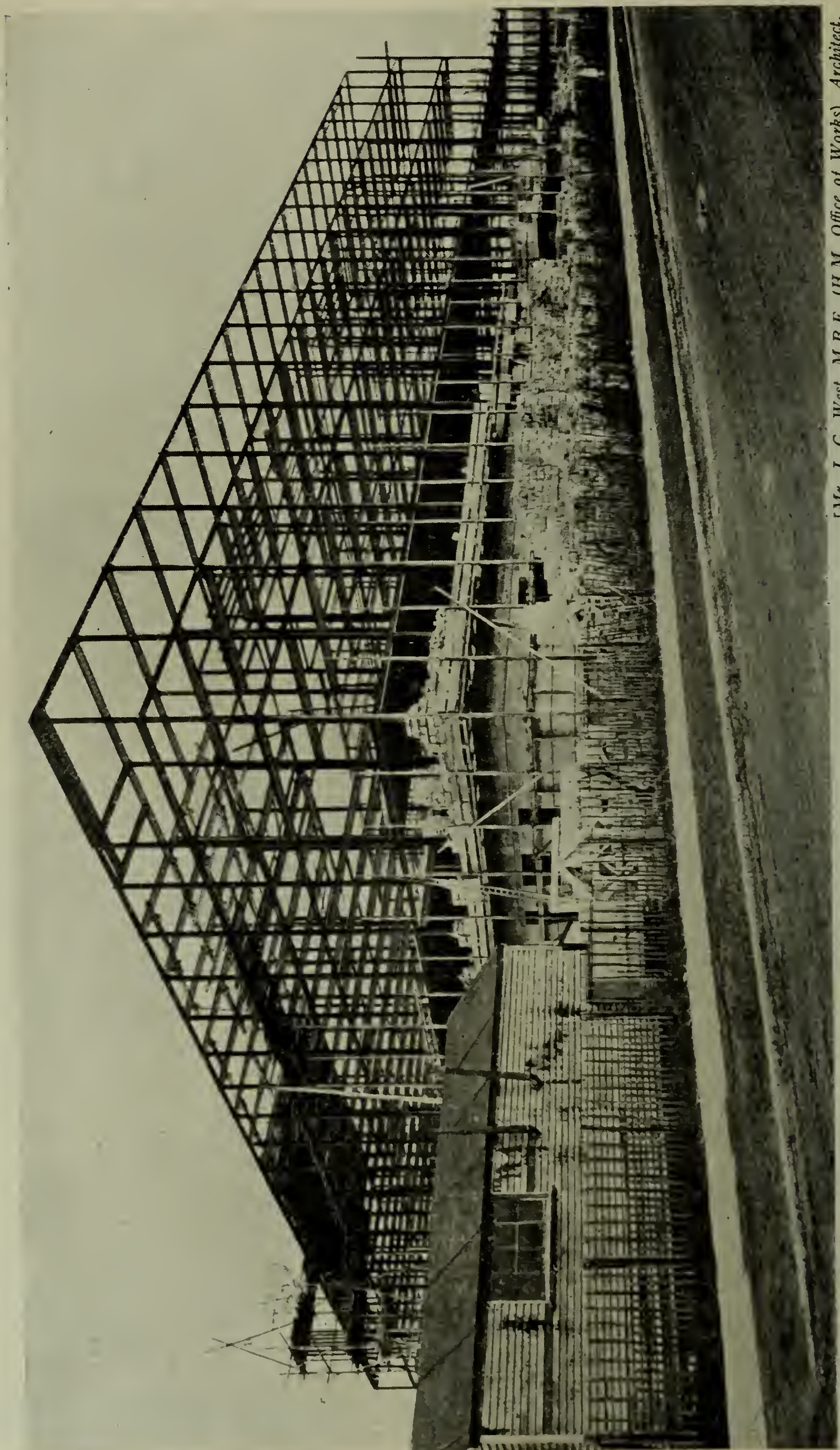
AERIAL VIEW OF THE NEW PENSIONS BUILDING AT ACTON: DURING CONSTRUCTION. (See p. 505.)

[Mr. J. G. West, M.B.E. (H.M. Office of Works), Architect.

THE NEW PENSIONS OFFICE, ACTON.

THIS building, which has just been completed, gives, on the whole, a very good account of itself architecturally, and shows how well concrete can adapt itself to architectural ends. There is much that is becoming in its dignified plainness, the mere absence of fussy detail, and in its frank acceptance of truthful construction and use as an end in itself, without the imposition of superfluous details—which are in most cases a bad habit, and, moreover, expensive—and to which the becoming simplicity of this building is much to be preferred. The main façade of the building contrasts admirably with the well-proportioned and excellently-planned entrance porches, which include just what is necessary to give emphasis and contrast in the building. They seem to us to be just right in mass, and are neither dwarfed by the size of the rest of the building nor too large to secure the

THE NEW PENSIONS BUILDING, ACTON: ONE OF THE MAIN ENTRANCES.



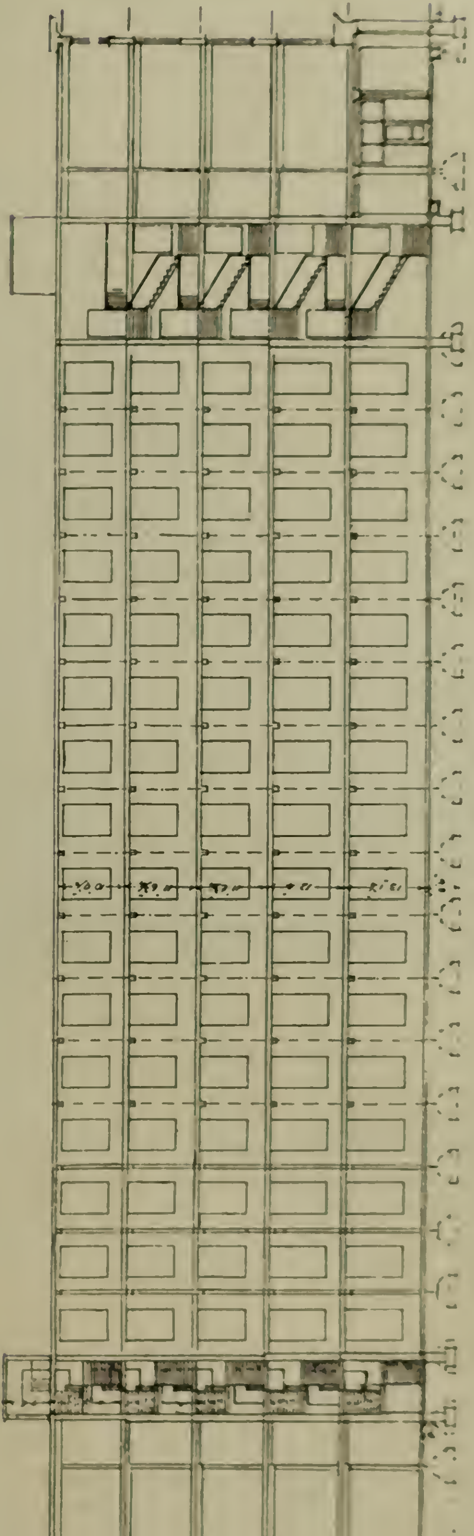
[*Mr. J. G. West, M.B.E. (H.M. Office of Works), Architect.*

THE NEW PENSIONS BUILDING AT ACTON: DURING CONSTRUCTION.

right contrast. The roof cornice has a projection of 4 ft., and has been designed as a thin slab.

There is reason to be very well satisfied with the result of a building in which economy had to be the paramount consideration, and the use of concrete for such a result is a further endorsement of the material for architectural use. As necessity is the mother of invention, so financial stress is constantly found not to be quite the obstruction it appears; on the contrary, it stimulates us to the creation of wealth in new ways. Man becomes more and material things less. Here is a building the erection of which is to be regarded as governed by utilitarian necessity—a strictly enforced economy. It does not suffer thereby in external appearance but has actually more of intrinsic architectural character than vastly more expensive buildings. The pretension generally associated with Government buildings, which has made them very expensive without making them any better, in this new Pensions Building disappears and gives place to a better thing, with the requirement of good architecture kept in a righter proportion. It cannot be too often insisted that what we need is rest from much of the extravagance fostered in public expenditure at the cost of the national life, and to free ourselves from much obsolete doctrine of what they should include. The reaction on architecture is bound to be considerable, and it is particularly fortunate for the prospects of concrete as a building material that its use should become associated with some of the best results connected with this more enlightened point of view.

This is a vast rectangular building, 540 ft. long by 247 ft. wide, five stories high, without projections or effects. Accentuation is given to the corners by projecting quoins, and the whole is crowned by a widely-overhanging cornice, carried on plain unmoulded brackets arranged in pairs. The horizontal divisions occur above the ground floor (which is rusticated and forms a base) and below the top floor, where there is a string-course, the space above this forming a frieze, the projecting quoins being here dispensed with. Except for the projecting porches on the long elevation and the subsidiary doors on the others there is no other feature or embellishment of any kind.



Section C—D. (*See plan pp.* 544–5.)

The New Pensions Building, Acton: Cross Section.

[A longitudinal section is given on pp. 544 and 545.]

The large sash windows, with their wide white expanse of architecture in the Queen Anne tradition, are beautifully proportioned, and it is largely owing to them that the appearance of the building is so satisfactory.

The planning is as simple and direct as the elevations. There is a periphery of offices, then long, direct, well-lighted corridors, and within the space is divided alternately into offices and wide grassy courtyards. The six office blocks, each 39 ft. 6½ in. wide, are arranged at right angles to the front, opening off a corridor which runs the whole length of the front of the building, and extend to the full depth of the building. These blocks are separated from one another by grass plots, five in all, each 61 ft. wide, which ensure ample light and air to each block, besides adding to the pleasantness of the building as a workplace.

At the east end of every court, on every floor, is situated a lavatory block. The whole makes for simplicity in circulation, good lighting and ventilation, and simplicity in construction.

The employment of concrete has proved most successful. No other material, indeed, would have been so adequate; the unit of a brick would not appear so happy in its effect, and stone would have been too costly and also unsuitable for so simple a treatment. Here, both colour and surface are pleasant, the joints of the blocks giving both interest and scale. The large bold mouldings, such as those forming the architrave to the subsidiary doors, are most satisfactory, and it is pleasant to see the marks of the shuttering on the underside of the great cornice—there is no need to be ashamed of these. The cornice itself is a remarkable example of the possibilities of concrete construction generally.

The buildings comprise three separate blocks; a large office block, a canteen, and a boiler house with workshops, etc.

The main office building, consisting of a ground and four upper stories, is rectangular on plan, 62 ft. high from the general level of the stanchion bases, and provides accommodation for a clerical staff of 5,200 persons. The structure generally consists of a skeleton steel framing, transmitting all loads to the foundations. The precast concrete staircases are, however, carried by the enclosing brick walls. The design of the steel framing has been arranged with a view to simple construction; built-up sections and bent pieces having been entirely avoided. The bays are set out to dimensions of 12 ft. 6 in. and 10 ft., and the various parts of the plan are generally multiples of these bays.

The floors are constructed with light, hollow, pre-cast reinforced slab beams grouted up in position, and the flat roofs are of hollow-tile blocks and reinforced concrete, the object of this construction being to reduce the dead loads to a minimum. Both floor and roof constructions take their bearings on the top of the main steel beams. These steel beams require no shelf angles or concrete haunchings and are left exposed and painted a suitable tint.

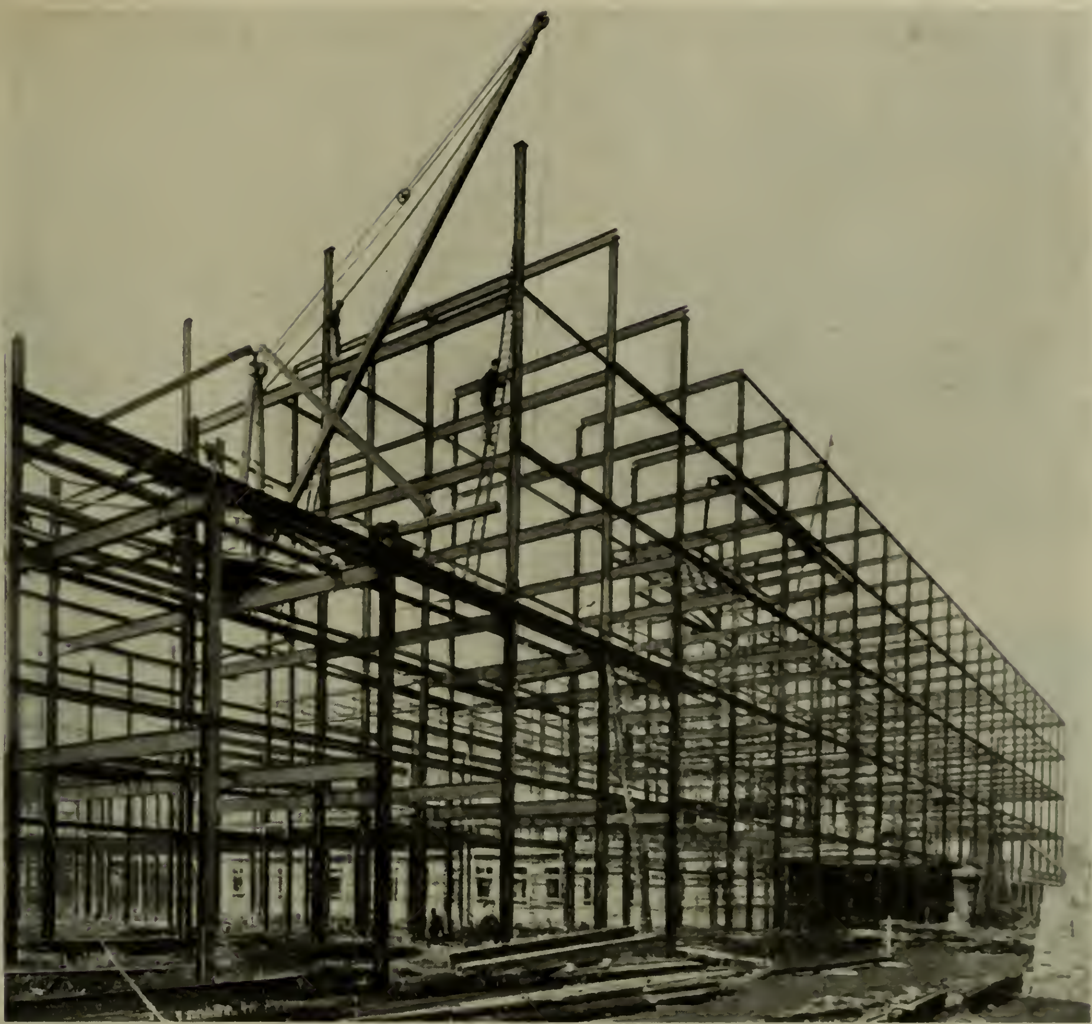
The external walls, except those to staircases and lift enclosures, act only as a covering to the structure and are built hollow of concrete blocks with an outer thickness of 4½ in. and an inner thickness of 2¼ in., with a 2¼ in. cavity between. The two thicknesses are tied together with galvanised ties. The wall panels are carried independently at each floor level on a steel beam and panel, encased solid with concrete. The walling is secured at intervals to the steel stanchions with specially-shaped iron toes embedded in the wall joints and concrete filling to the stanchions. The latter are encased with concrete only where the nature of the construction renders such treatment necessary; consequently some of the stanchions are erected unpainted and others painted.

The foundations are of plain concrete, and all stanchion bases are secured with long holding-down bolts.

Provision is made for storing water on the main roof over the lavatory bays in twenty 1,000 gallon tanks, constructed with solid walls carrying an independent roof, as the steelwork is not carried up above the main roof level.

The main cornice is of simple design and is anchored down at the rear by means of a continuous steel strap and anchor bolts embedded in a reinforced concrete lintel spanning the main roof beams.

The canteen is complete with kitchen, sculleries, stores, etc., under one roof, and measures 225 ft. long by 140 ft. wide. The accommodation has been planned on



The New Pensions Building at Acton : During Construction.

one floor only and the construction is similar to that in the main office building, but the lantern lights are all formed in the main steel framing, certain stanchions being carried up to a greater height for this purpose.

The boiler house, with brick chimney shaft, workshops, fuel store, etc., measures 94 ft. by 80 ft. Owing to the peculiar requirements of this one-story building, it was found that so much solid walling was necessary that the walls were made of solid brickwork throughout, the external elevations being faced with concrete blocks to match the other buildings. Internal stanchions carry the portion of the roof over the boilers, while over the surrounding workshops, etc., the roofs are carried direct by the walls.

The roofs of all buildings are of similar hollow tile construction.

The whole of the steelwork was designed, manufactured, and erected by Messrs. Dorman, Long & Co., Ltd. The whole of this work is self-supporting, all the load of the building being carried on the steel frame. The total amount of steel used in the building is about 2,000 tons, and the area covered 540 ft. by 245 ft.

A plan and longitudinal section of the building are given on pp. 544 and 545.

The whole of the four floors to this building have been carried out by the Siegwart Fireproof Floor Co., Ltd., in their well-known pre-cast hollow floors. The total area of floors supplied amounts to approximately 300,000 ft. super. The general spans throughout the building are 10 ft. and 12 ft. 6 in. A 5-in. floor was laid in the 10 ft. spans and a 6-in. floor in the 12 ft. 6 in. spans. The floors were designed to carry an inclusive load of 1¼ cwts. per ft. super. A test on

Siegwart beams which was carried out before representatives of H.M. Office of Works and members of the Concrete Institute, who paid a visit of inspection to the contract during course of construction, gave every satisfaction.

The building is to the design of Mr. J. G. West, M.B.E., of H.M. Office of Works. The main contractors are Walter Jones & Sons, of 64, Victoria Street, S.W., and among the sub-contractors employed were Stuart's Granolithic Co., Ltd., of 63, Lincoln's Inn Fields, W.C., for the granolithic work; The Siegwart Fireproof Floor Co., Ltd., of 231, Strand, W.C., for the pre-cast beams; The Kleine Patent Fire-Resisting Flooring Syndicate, Ltd., of 133, High Holborn, W.C., and Messrs. Diespeker & Co., Ltd., of 60, Holborn Viaduct, E.C.1, for the hollow brick roofs; Messrs. Dorman Long & Co., Ltd., of 4, Central Buildings, Westminster, S.W., for the constructional steelwork; Messrs. H. J. Cash & Co., Ltd., of Caxton House, Westminster, S.W., and Messrs. B. Finch & Co., Ltd., of 82, Belvedere Road, S.E., for the heating and sanitary installations; and The Alpha Manufacturing Co., of Harbesson Road, Balham, S.W., for the electric lighting.

The whole of the external blocks for the building were made at Frampton, on "Winget" machines.

Mr. A. L. Barber, clerk of works to the Office of Works, supervised the erection of the building.

THE NEW PENSIONS BUILDING, ACTON: FLOORS DURING CONSTRUCTION.

THE BANK OF BRITISH WEST AFRICA, CASABLANCA.

The Bank of British West Africa, Ltd., established a branch in Casablanca, Morocco, in 1915, and business developed so rapidly that a new building to house the increasing staff was a necessity. A site having been secured in the rue du General Drude, the architect, Mr. H. Guy Holt, A.R.I.B.A., visited Morocco in 1919.

Preliminary sketches were prepared and the preparation of working drawings to a scale of ·02 metre commenced in November, 1919. It was at first intended that French contractors should be employed, but the building trade in Casablanca was at that date in a hopeless state, owing to the great demand for new buildings of all classes; on the advice of the architect it was decided to employ an English contractor, and a contract was made in February, 1921, with Messrs. Thomas & Edge, of Woolwich, who were already engaged as contractors on other work for the Bank in the Gold Coast and Nigeria, under the same architect.

GENERAL ARRANGEMENTS.

The building has been designed to make the best use of the site available, the awkward shape of which demanded special care in planning to obtain a symmetrical appearance in the interior of the Bank, and also to obtain the maximum width.

The central portion of the basement is utilised for Bank strong-room, book and document rooms, stationery and

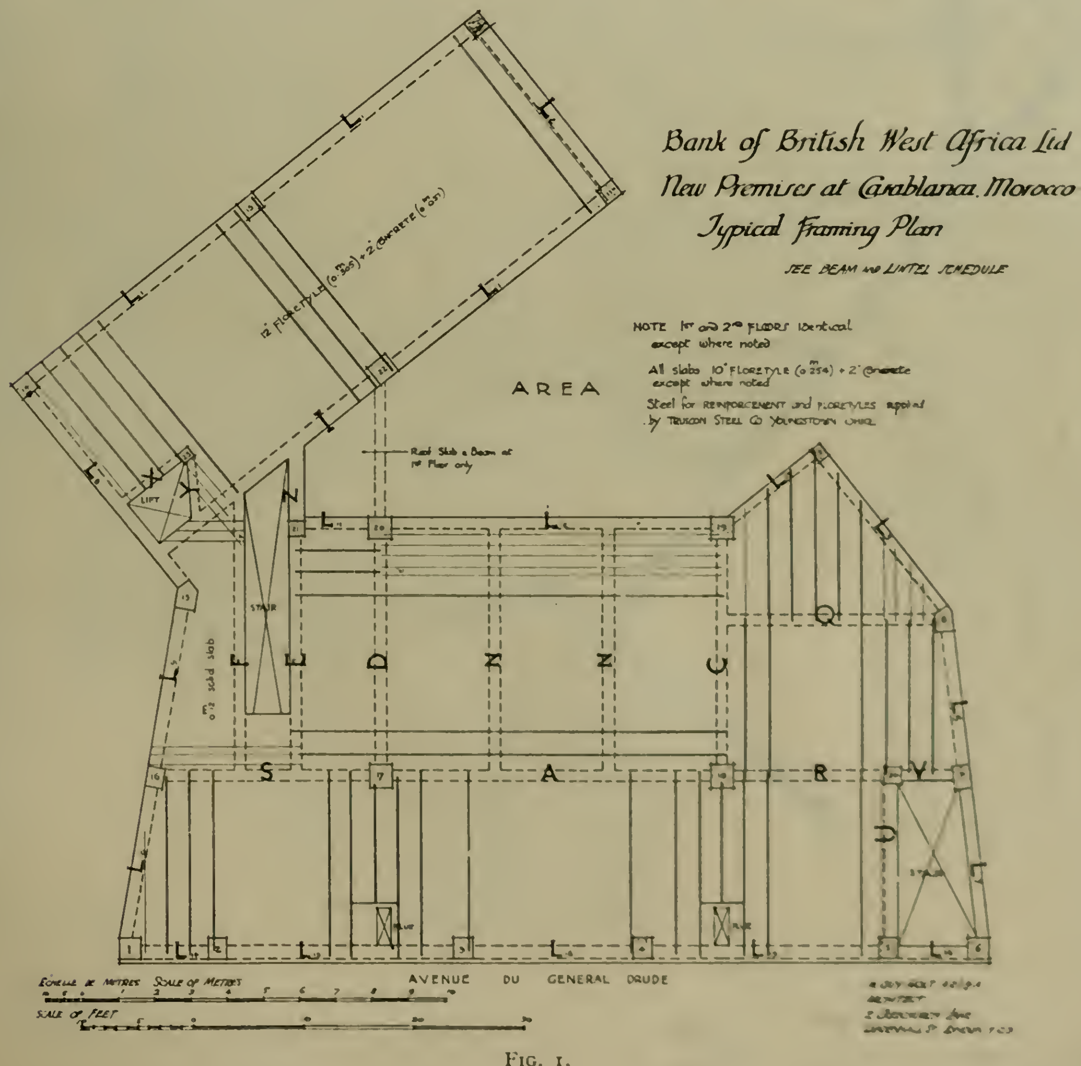
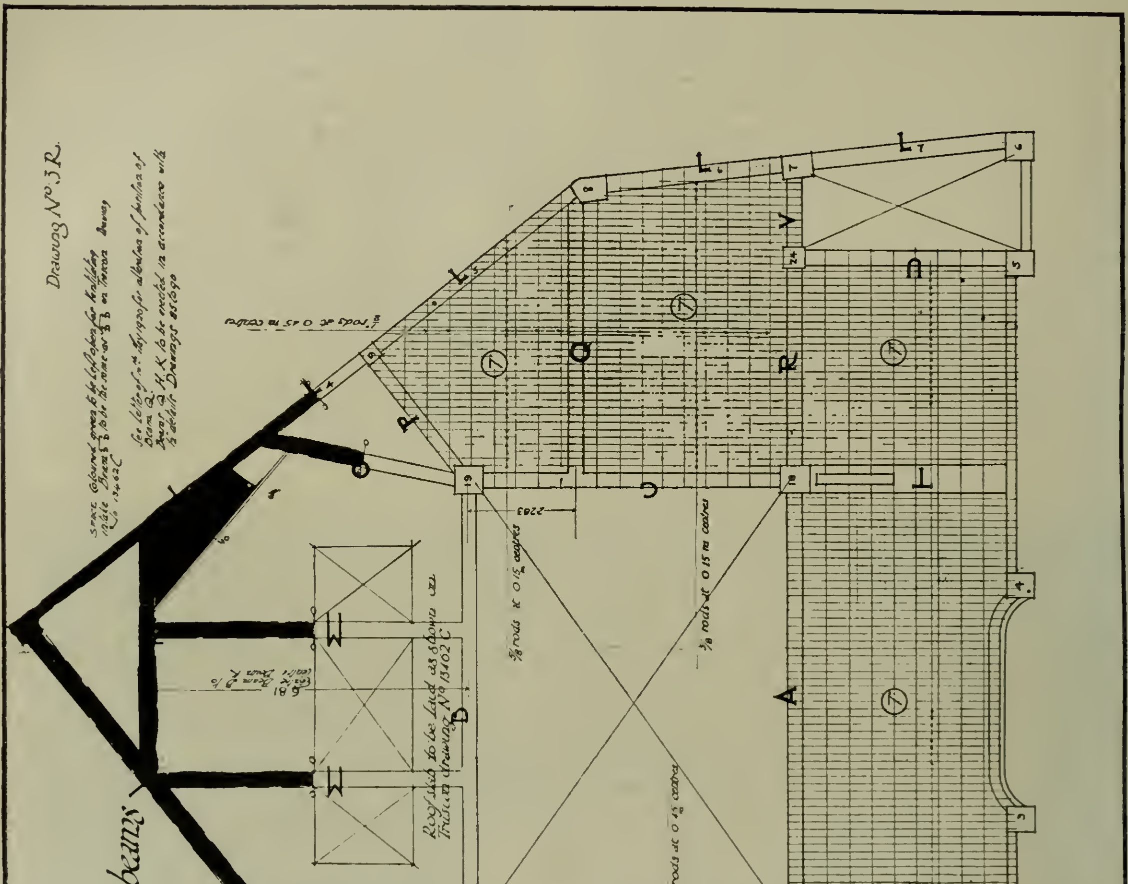
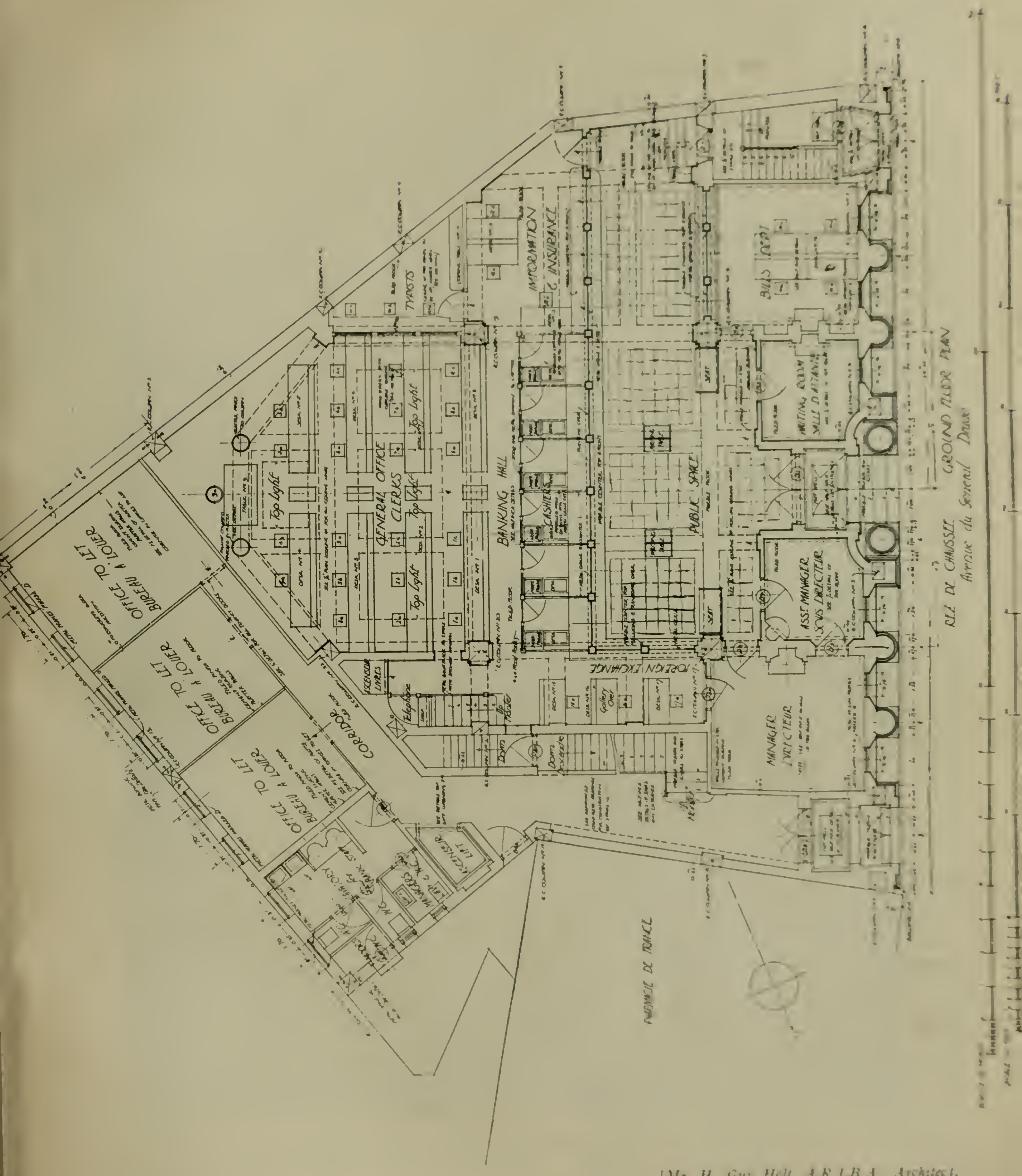


Fig. 1.



B.B.W.A. Casablanca.
Mezzanine Framing Plan showing beams & stanchions to be erected in front portion of building with round bar
Drawing No 3R.



[Mr. H. Guy Holt, A.R.I.B.A., Architect.

West Africa, Casablanca.

clerks' cloak rooms. This portion of the basement is approached by a private staircase from the Bank ground floor. The remainder of the basement is to be let.

The banking hall is on the ground floor, with a central entrance; on the left is the entrance to the offices to be let on the upper floors, with staircase and electric passenger lift. On the right is the private entrance and stairs to a flat on the fourth floor; this staircase is also available as an emergency exit. The main banking hall is taken through the mezzanine floor, giving a total internal height of 7 metres. A gallery is arranged at each side which will be used by the Bank as additional clerks' accommodation, and at the front is a suite of offices to be let, together with a room for the District Manager of the Bank in Morocco. Originally it was intended that the first, second, and third floors should be let as offices, but after the building was commenced the Bank decided that quarters must be provided for the District Manager and the Manager of the Casablanca branch. Later on it was decided to add a story to the building, and although this is not strictly permitted by the local by-laws, consent was obtained from the French authorities. Thus, radical changes had to be effected whilst the building was actually in progress. The front of the third floor is available for letting, but the rear portion is utilised as a flat containing a small salon and dining-room with folding doors between, two bedrooms, kitchen, and offices. On the fourth floor the District Manager's flat is at the front of the building. Rooms for Moorish servants, wash-house, etc., are arranged on the main flat roof level.

The main elevation to the street is 24·28 metres wide, and 23·68 metres from pavement to top of parapet. The elevation has been designed to emphasise the Bank portion of the building, with Greek Ionic columns, having the flutes cabled from top to bottom, and pediment over the Bank entrance. The bright light of the pure Moroccan atmosphere does not require such large windows as would be necessary in this country, and moreover they must have jalousie shutters to close during the heat of the day, if necessary. Fireplaces are not essential, but desirable in living-rooms for an occasional fire during the rainy season.

CONSTRUCTION.

A reinforced concrete skeleton framing was decided on as being cheaper than a steel-framed building, with reinforced columns and beams required at the main points; infilling to outer walls is in rubble masonry, in which the Moorish workmen are adept. The building is on hard limestone rock, and the excavated material has largely been used for the rubble of the walls, after being roughly squared on the job, and the fine stuff has been used in mortar and concrete.

The steel for reinforced concrete work and the steel floor tiles and "Hyrib" for the floors were supplied by the Trussed Concrete Steel Co. of America. Owing to railway, steel, and coal strikes in America, about 10 tons of British steel round rods and wire were shipped at an early date and arrived in ample time to complete the footings for the columns, columns up to ground floor level, and beams at that level. In order to dispense with large reinforced concrete beams in the ground floor, for which special steel lengths would have been required, the original basement plan was modified and additional division walls between the rooms were provided to shorten the floor spans. Thus the walls and columns were up to the ground floor level and the floor slabs concreted before the arrival of the steel from America. But for this a delay of at least two months would have occurred.

Loads were calculated as follows on the basis of an equivalent distributed dead load additional to weights of floors and ceilings: Ground floor (Bank), 120 lb. per ft.; mezzanine floor, 120 lb. per ft.; 1st, 2nd and 3rd floors, 120 lb. per ft.; and 4th floor and flat roofs, 100 lb. per ft.

A typical framing plan is shown in *Fig.* 1.

Special construction at the mezzanine and first-floor levels was necessary on the front wall owing to the architectural recessing of the centre bay to allow of detached circular columns at the Bank entrance, and a beam curved on plan at each end was used here; on the upper floors the two main T-beams were designed with an oblong vertical hole through the centre to leave space for the smoke flues from the fireplaces. At the rear portion large half T-beams were used as lintels at the window head levels spanning

[Mr. H. Guy Holt, A.R.I.B.A., Architect.

FIG. 10.—BANK OF BRITISH WEST AFRICA: IN COURSE OF CONSTRUCTION.

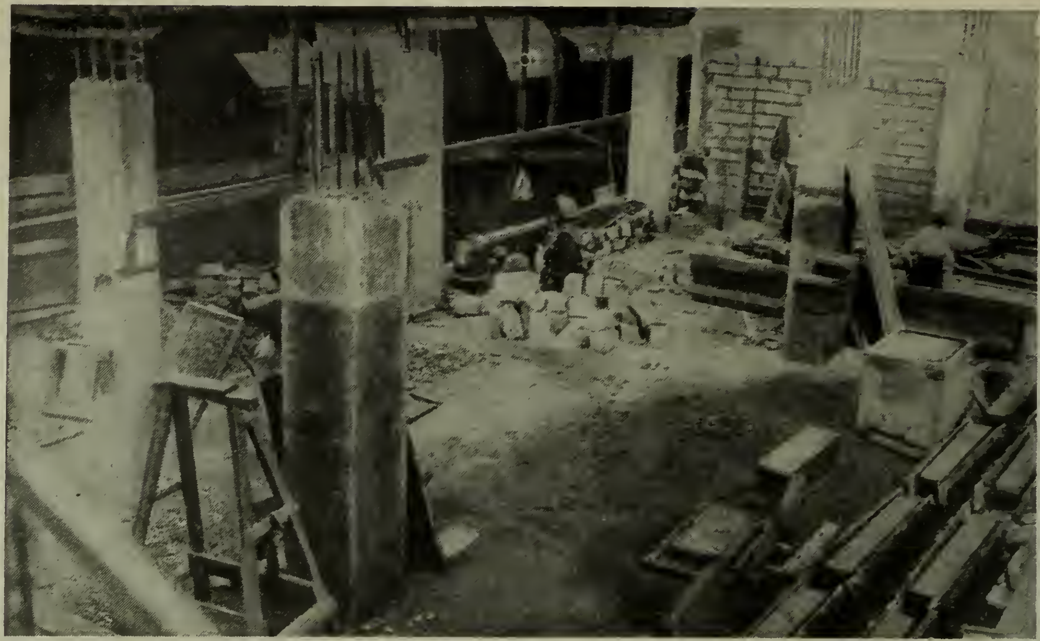


FIG. 2.

FIG. 3.

FIG. 4.
THE BANK OF BRITISH WEST AFRICA, CASABLANCA.

FIG. 5.—VIEW FROM FRONT OF FIRST FLOOR TOWARDS BACK WING UP TO SECOND-FLOOR LEVEL.

FIG. 6.

between the centre and end columns. These beams are 0·60 m. deep and 0·35. m. wide and 1·52 m. over T. Solid floor slabs were used on the staircase landings; the main floors of the building were constructed with 10-in. steel floretyle and 2-in. concrete over, laid on "Hyrib" for plastering. The floors are finished on top with Spanish white tiles, except the public space of the banking hall which has marble slab flooring in black, white, and grey bands and panels.

PROGRESS OF THE WORK.

The congestion in the Casablanca building trade at this time was such that the whole of the plant and tools and scaffolding had to be shipped from England to the job. In order to save time the opportunity to forward various consignments before the contract was entered into, consisting of Portland cement, steel round bars, etc., was utilised. The advantage of this soon became apparent.

Two of the contractor's foremen arrived on the job in the middle of March, 1920, and commenced getting together a staff of local workmen. This in itself proved a sufficiently difficult matter as a sort of auction mart of floating native workmen was held in the native market and contractors were bidding against each other from 6½ to 7½ francs per day; moreover, the harvest was ripe and labour scarce in consequence.

Great trouble was experienced in obtaining delivery of the materials and plant shipped out, owing to the lack of organisation and supervision by the French port authorities, and bad handling resulted in much breakage. Two steamers arrived with material and plant early in April, and were unloaded forthwith.

On March 22, 1920, the clearing of the site commenced, and temporary sheds were erected. A space was set aside for the storage of cement and other materials and a plot of land adjoining the site was secured temporarily for the bulk of these.

Excavation for columns 1, 15 and 16 against the wall of the *Pharmacie* adjoining was commenced, as it was desired to get in these columns to act as buttresses to the rubble wall. With ordinary tools the progress was very slow (about 18 in. in three days). Blasting was commenced on March 30. Some of the stone removed was of poor quality, but selected stones were set aside and roughly squared for walling. From the débris, after blasting, a considerable quantity of sand was obtained and sieved through for subsequent use. A *compresseur*, or drill, was obtained in May and facilitated progress, although this continued to be slow owing to the fact that few men could be employed on account of the blasting operations. Further, the Mohammedan Ramadan was now on for a month, during which period no Moor eats between 3 a.m. and 9 p.m., and their efficiency suffered considerably in consequence.

The back portion of the building was excavated first, and by April 15 the basement window lintels of the back wall were up to the underside on the ground-floor level. At the end of May the chief foreman, Mr. W. H. Wiles, was taken ill, and, to the regret of all who knew him, died of typhoid fever. There was a shortage of water in Casablanca at this time, and it was not before July that a supply was eventually laid on to the job.

Early in July a stone crusher was delivered on the job, and the crushing of stone for concrete was got well in hand. Other difficulties cropped up and labour was very scarce. The levelling of the site for the basement floor and rock cutting for the column foundations were completed in this month, and good progress was made in the fixing of the steel and concreting of the columns up to ground-floor level, erection of steel strong room, etc. Mr. J. E. Evans, the general foreman sent out to take the place of the late Mr. Wiles, arrived in Casablanca in August, as also did Mr. Gibson, foreman carpenter, who was specially selected for his knowledge of reinforced concrete form work. Mr. Evans at once set about re-organising the job, and from the date of his arrival rapid progress was made.

Fig. 2 shows the progress made by September 27, looking towards the front street at the ground-floor level; boxes for making concrete blocks for internal walls are seen in the foreground. The columns shown in this view are almost up to the level of the mezzanine floor, and it was not until this level was reached that the steel supplied by the Trussed Concrete Steel Co. arrived, in October. Sorting and straightening this steel occupied some time, but the mezzanine floor was put in with floretyles. This construction was adopted to give a fairly soundproof floor, as most of the buildings in Casablanca are very noisy owing to the tiling of all floors on solid concrete. The procedure adopted on the job was as follows: The whole area to be floored was sheeted in and propped, and "Hy-rib" spread over this; floor tiles were then spaced according to plan, leaving small reinforced T-joists between each. The reinforcing consisted of "Kahn" bars specially provided. Concrete was then poured.

Fig. 3 shows a view of the front elevation with rubble walls up to mezzanine level and columns with rubble core and concrete finish left for cement casts from England. *Fig.* 4 is a view from the back showing the mezzanine floor concreted and the flat roof at the bottom of the area, with sheeting to two well holes for lantern lights. The hoist is in the foreground.

At the end of November, 1920, the architect paid a visit to Casablanca in company with Mr. J. M. Lawrie, of the Trussed Concrete Steel Co. A number of snapshots taken by the architect, shown in *Figs.* 5 to 9, illustrate various points in the construction of the building. On December 16, 1920, most of the walls and columns were up to the first-floor level and portions of the first floor had been sheeted for and concreted. Very rapid progress with the structural work was now being made; by the first week in January, 1921, columns supporting the second floor were concreted to underside beams, and walls carried up to the same level; the stone crusher for aggregate was kept running night and day in order to maintain the output required, as it was impossible to buy aggregate locally, and the selected material from excavation which had been stored in readiness at the back of the site was used.

A foreman plasterer was sent out during January to supervise all the exterior cementing and fixing of cast cement work, supplied by Messrs. G. Jackson

FIG. 7.

FIG. 8.

FIG. 9.

& Sons, London, together with internal plastering and French stuc plaster to the Bank interior.

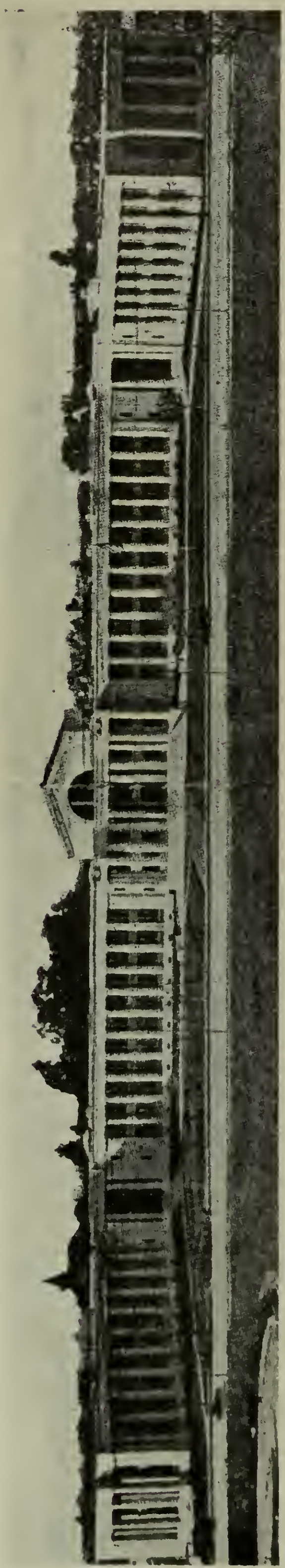
At the end of January columns and walls were up to the third-floor level.

Consent of the local authorities to an additional story on the building was now anxiously awaited, and lack of this began to hinder progress. By February 9 concreting to the whole of the third floor and the staircases leading thereto was finished, and constructional work was at a standstill pending instructions with regard to the additional story, consent for which was finally obtained. Meanwhile, plastering in the basement was commenced, and the running of fibrous cornices in moulds supplied from England, casting cement columns, etc., were in progress. Frequent breakages of material shipped from home necessitated constant replacements. At the beginning of March, 1921, columns and walls were up to fourth-floor level. Some of the beams supporting walls of the additional story, not originally calculated for, were strengthened on the advice of Mr. Lawrie.

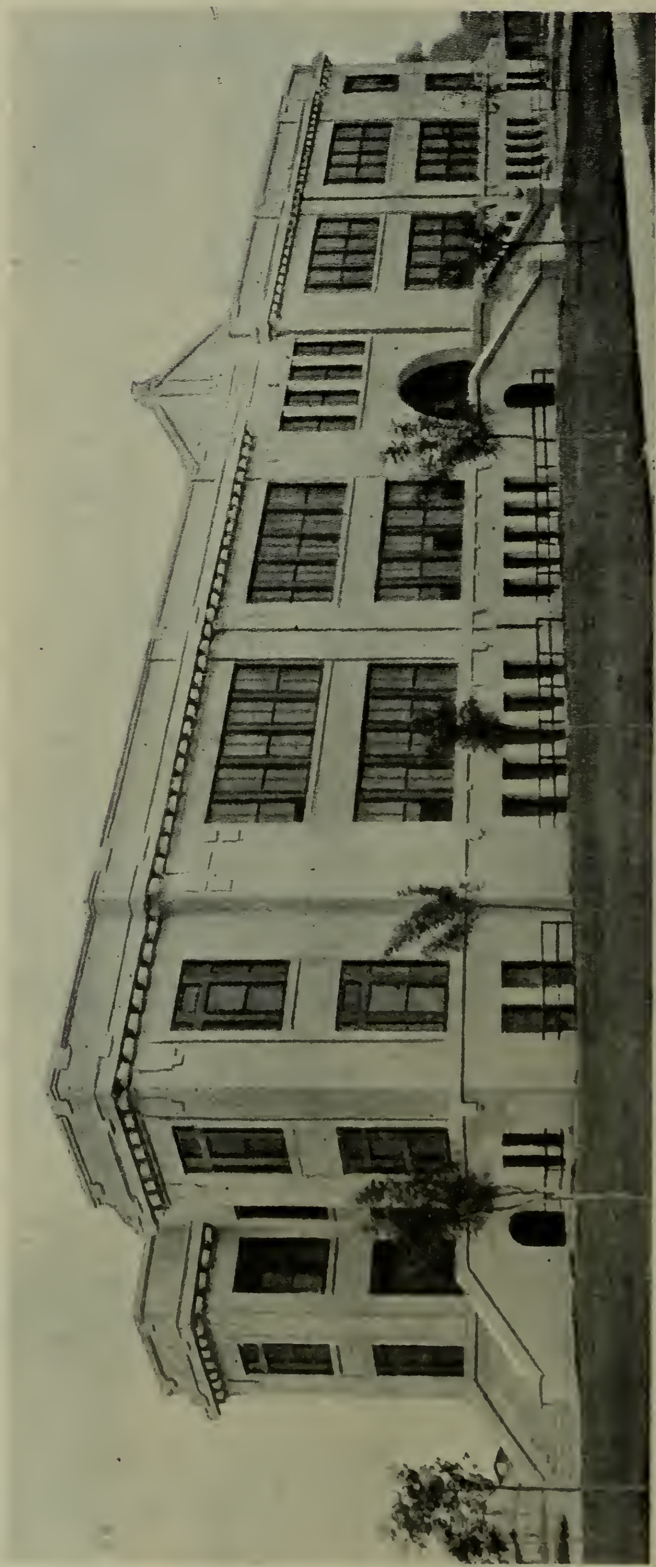
The walling up to the roof level was completed by the end of April. The main cornice was completed in June and July with parapet walls over.

Fig. 10 shows the front of the building taken on August 2, 1921, with the exterior cement work on main cornice and bands finished and down to third-floor level, jalousie shutters fixed to third and fourth floors and columns, capitals, and entablature and pediment to Bank portion, that is, up to first-floor level, finished. The main structural skeleton from footings, basement, ground, mezzanine, first, second, third and fourth floors and outbuildings on roof was completed in practically nine months, the excavation not being completely finished until the end of July, 1920, and the main roof completed by April, 1921; the three upper floors were finished at the rate of one story per month.

Considering the nature of the work, the class of unskilled labour employed, and the incidental troubles with the various languages (English, French, Spanish, Italian, and Arabic) used on the job, delays caused by shipping difficulties, and, last but not least, saints' days, fête days, and Moorish feasts and fasts on which little or no work was done, this was very rapid work. Sunday work has been carried on by the foremen when workmen have been available in order to make the desired progress. The average number of workmen employed per week has been about fifty or sixty, which compares very favourably with any job of the same size in this country and much better than jobs carried out by the same contractors in West Africa, where native labour runs into 150 men per week for quite a small job. The Moorish workmen may be described as being, generally speaking, very willing and tractable but stupid and slow. Some of them are, however, quite capable joiners and carpenters, and the masons who are accustomed to build in rubble are quite good at that work. They are new to reinforced concrete work, although there are numerous buildings in Casablanca and elsewhere in Morocco carried out in reinforced concrete by the French.



TECHNICAL HIGH SCHOOL, OAKLAND, CALIFORNIA.



Messrs. Trost & Trost, Architects.

SCHOOL AT ALTA VISTA, TEXAS.

CONCRETE SCHOOL BUILDINGS IN AMERICA. (*See p.* 521.)

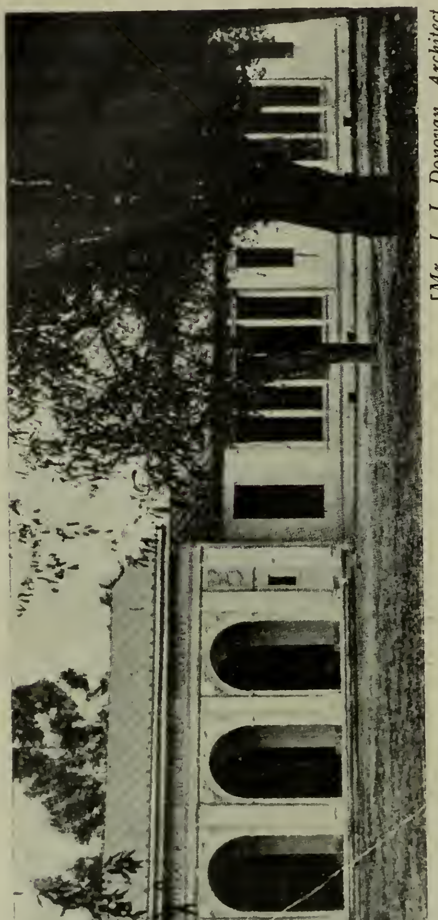
CONCRETE SCHOOL BUILDINGS.

As pointed out elsewhere in this issue, war-time industrial conditions and post-war finance have resulted in a very considerable amount of school building being postponed. The tendency at present is to make shift with temporary buildings, but the time cannot be far distant when a return will be made to the permanent type of school. During the eight years which have elapsed since schools were built in any number ideas with regard to their planning and construction have undergone considerable alteration, and this will no doubt be reflected in the new buildings when they are erected. Cost will, of course, be a primary consideration, but other factors must also receive much attention in the design and construction of a building in which up to a thousand children are frequently to be congregated at one time, and chief among these are fire-resistance and health. The fact that practically all modern factory buildings are built of reinforced concrete is sufficient evidence that concrete is the cheapest form of building construction and affords the best protection against fire, and one need only point to some of the large hospitals and sanatoria recently built to prove that it is at any rate not looked upon by the medical profession as inferior to other materials from the point of view of the health of the occupants.

There is, however, another aspect which must receive attention when the much-delayed school building is put in hand, and that is the architecture of the buildings. It is probable that when the erection of school buildings is once more proceeded with the conditions will be very similar to those prevailing when the Government launched its housing programme, namely, with speed of erection and economy in cost the ruling factors. If that be so it is also probable that these governing factors will be reflected in the architecture of the new schools, and that much the same result will be achieved in these buildings as in the new houses, where the elimination of the superfluous ornament which characterised the greater number of the small houses up to that time, and the better planning which came with the introduction of the architect on this kind of work, produced a vastly-improved standard of cottage architecture.

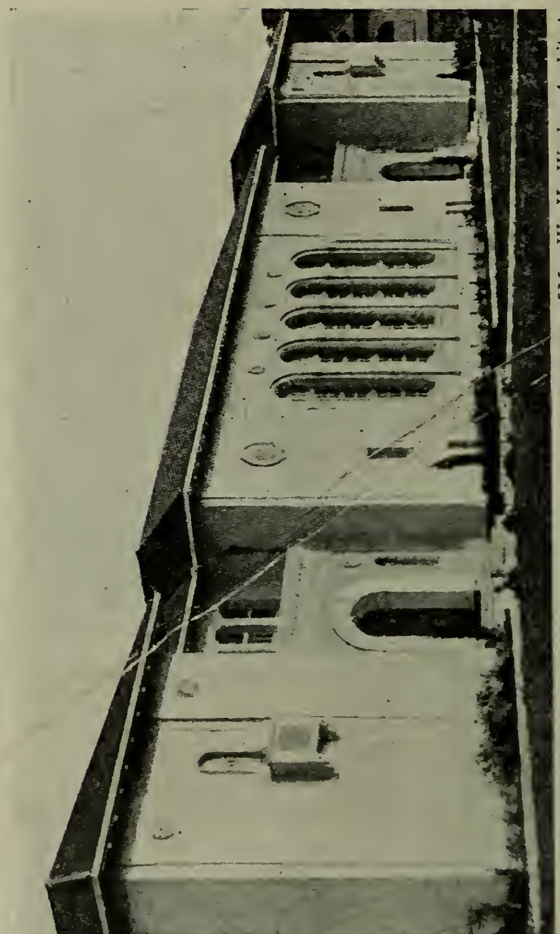
The illustrations herewith clearly show that the possibilities of concrete for school buildings have been grasped in America in the right spirit, and that attractive buildings eminently suited to their purpose can be built in the cheapest constructional material. These American schools show the adaptation of concrete to various styles of architecture, from the columniated style of the single-story buildings to the more modern design of some of the higher buildings. The cast concrete ornament, used with restraint, shows how well this type of decoration harmonises with the rest of the building.

Central Avenue School, Madison, New Jersey.



[*Mr. J. J. Donovan, Architect.*

LOCKWOOD SCHOOL, OAKLAND, CALIFORNIA.



[*Mr. W. H. Weeks, Architect.*

SCHOOL AT WATSONVILLE, CALIFORNIA.

CONCRETE SCHOOL BUILDINGS IN AMERICA. (*See p.* 521.)

ST. STEPHEN'S ROAD BRIDGE, BOURNEMOUTH.

This bridge was designed to carry a 25-ton vehicle with 15 tons maximum axle load at 10 ft. centres. It is constructed throughout of reinforced concrete, and is of the beam type, with a central span of 26 ft. 6 in. and two side spans of 11 ft. 9 in., making a total span of 50 ft. The minimum headroom over the lower road is 15 ft. 6 in. The bridge carries a roadway 50 ft. wide (carriageway 24 ft. wide and two footways each 8 ft. wide); and two ducts for the conveyance of water, gas, electric, and other mains are also provided. The whole of the mouldings and exposed faces were cast direct from the shuttering and left untouched.

The design is a freely treated Grecian Doric style, a feature being two groups of four monolithic columns. On each flank of the bridge two inscription tablets have been erected. These are of red Peterhead granite, ornamented with bronze lions' heads and festoons.

The first test consisted of running two rollers abreast across the bridge, each roller weighing 13 tons. The maximum deflection occurred on Beam No. 1 at the centre of the carriageway, and was recorded at ·0182 in.

The second test was with three rollers. Two rollers were abreast as before, each weighing 13 tons, and another roller immediately following weighing 8½ tons, totalling in all 34½ tons. The maximum deflection on the same beam was recorded at ·02 in.

The third test comprised three rollers as in test No. 2, travelling at high speed, i.e., 5 miles per hour. The recorded deflection was ·03 in.

In the fourth and final test two rollers travelled to the centre of the bridge. These were followed by a third roller, and all three were lined up abreast at the centre of the span. The total deflection in this case was recorded at ·03 in., as in the third test.

At the completion of each test, and also at the completion of the whole of the tests, there was a complete recovery of the beam, the instrument returning to zero.

The beams referred to have a span of 26 ft. 6 in. and a total depth of 24 in., or a net depth of 20½ in. The ratio of depth to span is therefore 1/15·5.

When it is remembered that the bridge was designed to carry a rolling load of 25 tons, and the test load actually applied totalled to 34½ tons, the test may be considered a severe one.

The engineer for the bridge was Mr. F. P. Dolamore, F.S.I., Borough Engineer of Bournemouth. The contractors for the constructional work were Messrs. Grounds & Newton, of Bournemouth, and for the reinforcement Messrs. The Indented Bar & Concrete Engineering Co., Ltd., of Westminster. The ornamental wrought-iron lamp standards were executed by Mr. J. Caslake, of Bournemouth, and the bronze work of the inscription tablets by Messrs. W. Morris & Co., Ltd., of London.

St. Stephen's Road Bridge, Bournemouth, during Construction. (*See also p. 521.*)

St. Stephen's Road Bridge, Bournemouth. (See p. 523.)

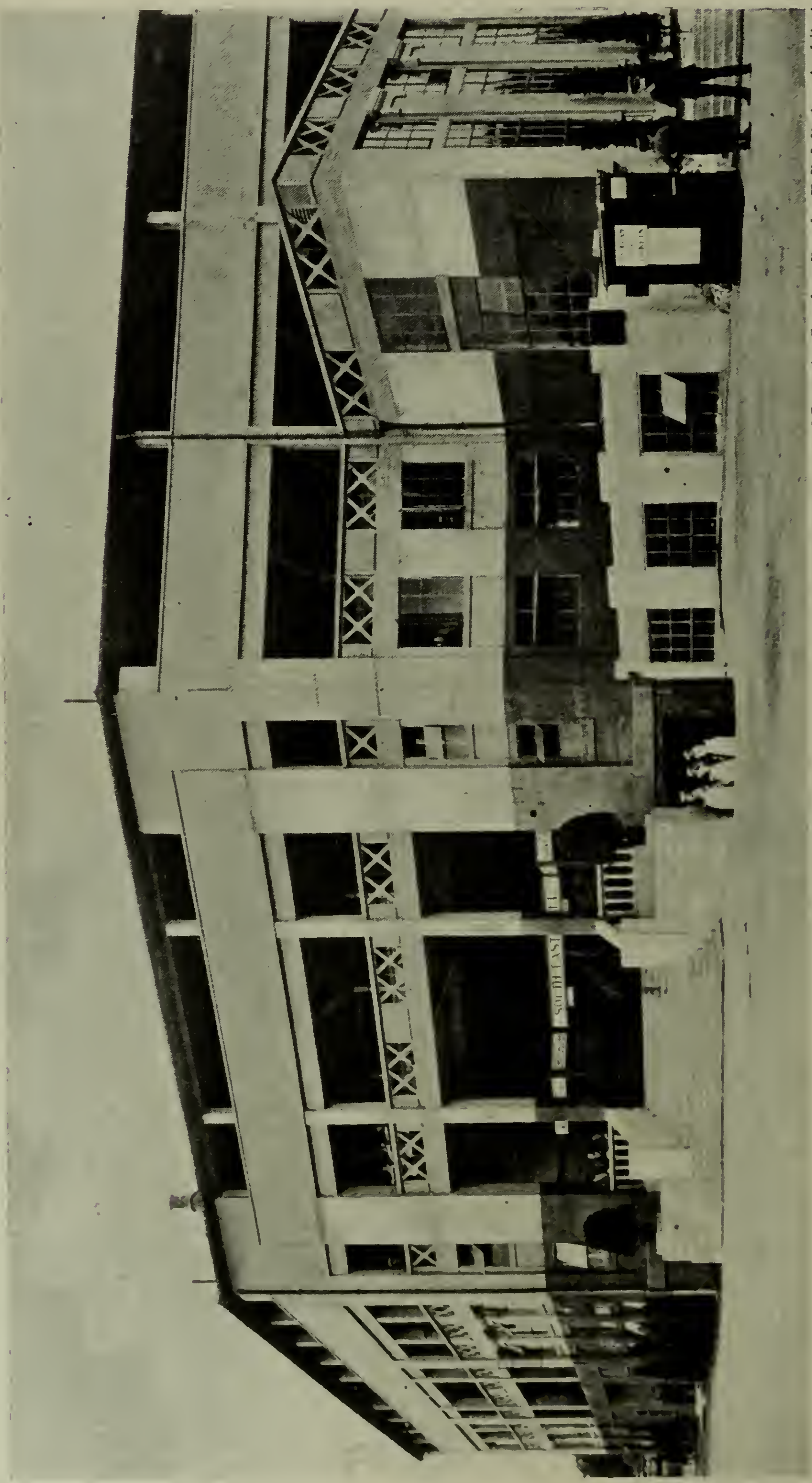
THE NEW ALL-ENGLAND LAWN TENNIS STAND.

To the architect, engineer, and all concerned with concrete construction, there is much of interest at the All-England Lawn Tennis Ground at Wimbledon besides the play, for the large stand erected around the centre court is unique in many respects. Except for the doors, window frames, seats and roof, this large structure, with its accommodation for 14,000 spectators, its covered area of 46,500 square feet, and its three miles of seats, is built entirely of reinforced concrete, and no attempt whatever has been made to disguise that fact. As economy in cost and time—especially the latter—were the prime factors to be considered in the work, the architect, Captain C. Stanley Peach, F.R.I.B.A., and the owners of the ground (Messrs. The All-England Tennis Ground, Ltd.) early decided that reinforced concrete was the most suitable material for the construction of the stand, and the structure was limited to the necessities of sound building without the addition of any extraneous ornament. The construction was, in fact, reduced to the bare minimum consistent with the accommodation to be provided and an adequate margin of safety, and the construction left to find its own expression and form its own architecture—with what excellent result may be seen by our illustrations. "The texture of the surface, which has not been touched since the removal of the shuttering, is excellent," says *The Builder* in an appreciative article on this building; "in places it has been covered with a light green distemper in order to help the players by providing a darker background to show up the balls more clearly and it would probably considerably add to the appearance if the whole of the structure were treated in the same way. The balustrading and railing, all of concrete, have an appearance of lightness which is not generally associated with the material, and relieve any heavy effect which might be given by the remainder of the stand." This opinion we can fully endorse, especially the reference to the air of lightness which the columns and balustrading give to the whole structure. The building is, in fact, an excellent reply to those who look upon concrete as a material which cannot be divorced from massiveness and solidity.

The interior of this building is also in

[*Captain Stanley Peach, F.R.I.B.A., Architect.*

THE ALL-ENGLAND LAWN TENNIS STAND: THE TEA ROOM.



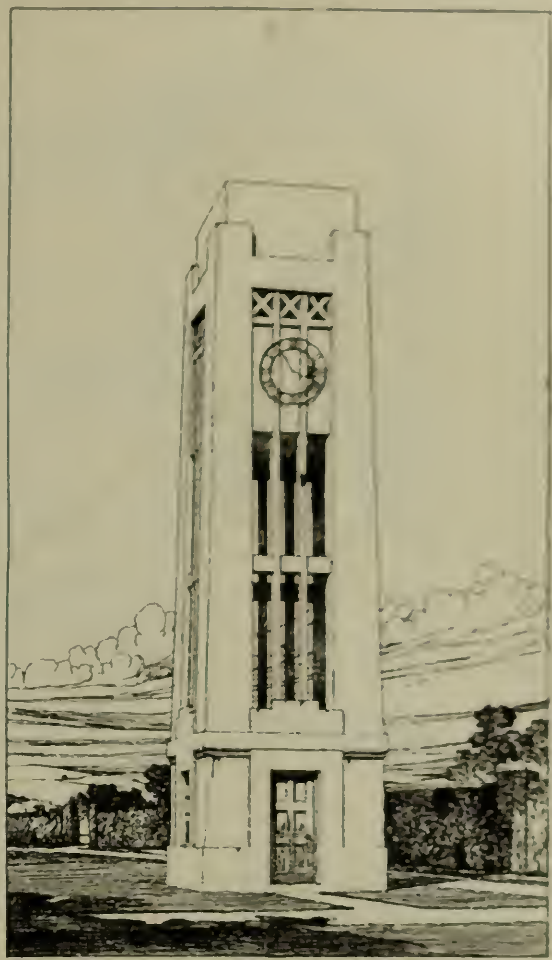
[*Captain Stanley Peach, F.R.I.B.A., Architect.*

The All-England Lawn Tennis Stand: Main Entrance.

many respects remarkable, and here again we might quote from our contemporary : " Although no attempt has been made at decoration or covering the concrete, the interiors of the various committee rooms, halls, tea-rooms, and especially the Royal rooms, are very pleasing. The keynote is simplicity and effect obtained by proportion. The tea-rooms, situated under the stepping of the stand and overlooking a lawn and some of the open courts, are well adapted for their purpose ; indeed, the restfulness which is here obtained by the absence of decoration might well be studied by those responsible for the design of the over-elaborate and fussy tea-rooms often to be found elsewhere." In the Royal rooms the walls are of pink plaster blocks, the wall surface being broken only by the joints between the blocks, which are emphasised by very distinct pointing. Pink plaster blocks are also employed in the main entrance hall and staircase, whilst for the other partition walls breeze-concrete blocks are employed.

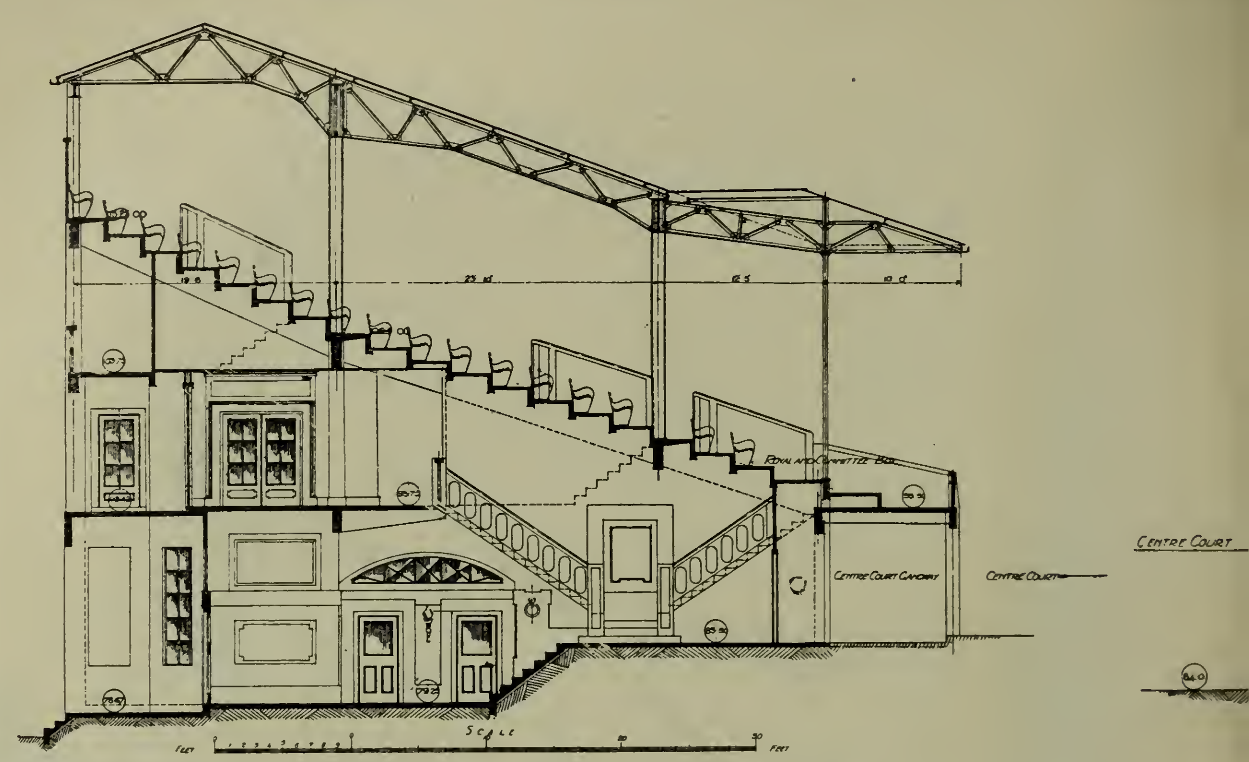
Work was actually commenced on the site last September, and the stand was practically completed and opened by the King in June, much of the work having been carried out during the winter months. The main stand, which gives covered seating to approximately 10,000 spectators, has four rings of columns, those in the third ring (counting from the outside) being at 10 ft. and 20 ft. centres. These columns are connected by main beams which carry the raker beams spaced at 10 ft. centres. The supports are widely spaced, and occupy only ½ per cent. of the total area covered, the entire area of the covered portion of the stand being 46,500 sq. ft., and that occupied by supports 248 sq. ft. The risers to the steppings are formed by pre-cast beams, and the method of erection was as follows : the centering to the main beams and raker beams was erected and the steel reinforcement fixed into position ; the centering to the tread of the stepping was then fixed, and the pre-cast risers hoisted and fixed into position. After the risers were fixed the actual concreting of the beams and treads was commenced.

The design of the stand was largely influenced by the slope of the site, which falls 30 ft. from one side to the other, and the space which has accrued below the steppings owing to the fall of the ground has been utilised to provide two intermediate floors, which extend from the centre of the south bay to the east. The space furnished by these floors is utilised to provide rooms for the administration, dressing rooms, upper refreshment room, etc. A lower ground floor gives the necessary catering accommodation. Exits from the steppings connect with galleries at their respective levels. The upper gallery is of rather unusual construction, being supported on the inside by hangers which transmit the load to the raking beams above. Between the main stand and the centre court are open steppings, providing accommodation for approximately 4,000 people. The construction of this part of the work is not exactly similar to that of the main stand. Here reinforced concrete frames at 20 ft. centres form the main supports, the risers to the steppings forming secondary beams. The four rows of steppings next the centre



[*Captain Stanley Peach, F.R.I.B.A., Architect.*

WATER-TOWER FOR THE ALL-ENGLAND LAWN TENNIS GROUND.



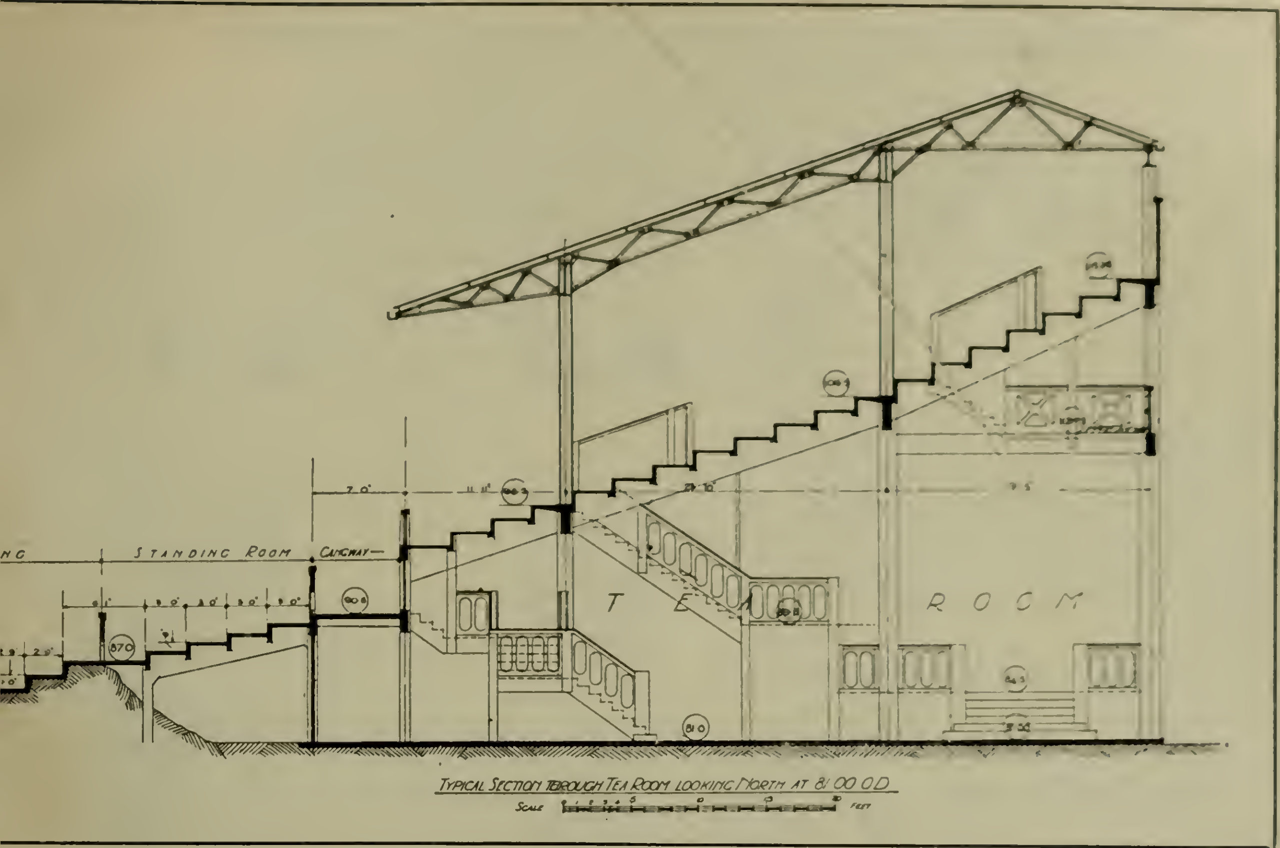
Transverse Section on Centre Line of Royal and Committee Entrance, Pavilion Road looking West.

court are constructed on the solid ground.

There are four main entrances, with large halls immediately inside leading to the staircases, and two other entrances. The farthest seat is 49 yds. from the centre of the court, and in no seat is the view interrupted, the piers supporting the roof, owing to their small size, being negligible. Ventilation is by open spaces under the roof and behind the back tier of seats. The roof is so constructed that while the court is open to the sky the shade does not fall on it until after 7 p.m., and then only on a small corner.

The whole of the reinforced concrete is on the "Kahn" system, from the

The All-England L



designs prepared by the Trussed Concrete Steel Co., Ltd., of 22, Cranley Gardens, S.W.; the general contractors were Messrs. Stuarts Granolithic Co., Ltd.; the general furnishings and the whole of the internal fitting of the stand was carried out by Messrs. Mullen & Lumsden, Ltd.; other sub-contractors were as follows:—Steelwork and roof, Archibald D. Dawnay & Sons, Ltd.; sanitation, heating, and drainage, Davis, Bennett & Co.; jointless flooring, Nuroads, Ltd.; wall tiling, Martin Van Straaten & Co.; painting of roof, gutters, etc., Aerograph Co., Ltd.; sand, ballast, etc., John Bennett.

Stand: Interior. *Captain Stanley Peach, F.R.I.B.A., Architect.*

ARCHES WITH PARTIALLY FIXED ENDS.

By R. N. STROYER, B.Sc., M.I.Mech.E.

In constructing reinforced concrete arches the designer has the choice between hinged and hingeless structures, each having certain advantages and drawbacks which may influence the choice in each particular case. A three-hinged arch is statically determinate, and therefore much easier to calculate for any given loading than the solid arch with fixed ends; temperature changes do not induce extra stresses, and as even considerable settlements of the piers or abutments do not cause any stresses or tendency to failure, the three-hinged arch is eminently suitable where there is a likelihood of the supports giving way or altering from time to time.

The two-hinged arch is statically indeterminate with one unknown reaction, the horizontal thrust; and although vertical settlements would not affect the arch, any horizontal movement of the supports or any temperature changes induce considerable stresses in the ring. If the extent of the horizontal movement is known it can be taken into account in the calculations, just as are the temperature changes, but if there is any danger of the supports giving way horizontally from sources which cannot be calculated the one assumption for the computation of the horizontal reaction does not hold, and the computation is worthless.

Still more is this the case in the hingeless arch where fixed ends are assumed. The solid arch is statically indeterminate with three unknown reactions, the horizontal, the vertical, and the bending moment; and, with the assumption of fixed ends, these are found by expressing that the abutments allow no horizontal, vertical, or angular movement. The solid arch is the form most suitable for reinforced concrete, since it utilises to the full the monolithic properties of this material;

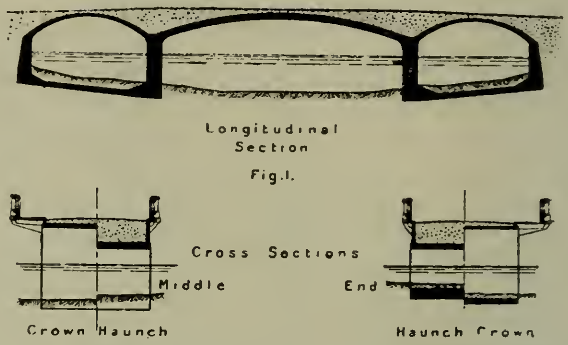


Fig. 1.—Coppermill Bridge: Typical Sections. Spans 50 ft. and 25 ft.

but, on the other hand, it generally requires very heavy and massive abutments in order to keep up the fixity assumption. If this assumption fails the whole of the calculations are affected, and if the extent of the movements, either horizontal, vertical, or angular, is unknown or incalculable the solid arch type is unsuitable and must be substituted by a hinged form of construction—to neglect any lack of fixity is to invite failure of the arch. If, however, the abutments are not absolutely immovable, but are known to be able to "give" to a certain limited and calculable extent, these movements can be accounted for and the stresses induced by them calculated in the same way as those caused by external forces and temperature changes. The writer proposes to give a few examples of arch bridges designed and erected under his super-

Fig. 2.—Coppermill Bridge.

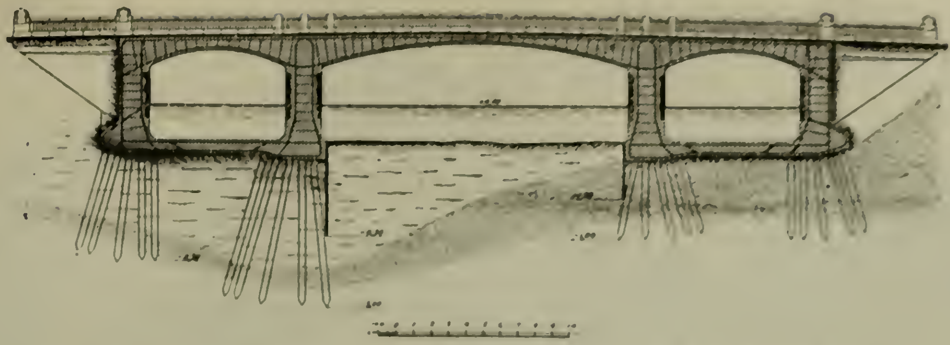


FIG. 3.—LANGENZUG BRIDGE: SECTION SHOWING FOUNDATION PILES DRIVEN INTO CLAY. SPANS 60 FT. AND 30 FT.

vision, where the movements of the supports have been taken into consideration and provided for in the manner just described.

Figs. 1 and 2 show the section and elevation of Coppermill Bridge, Wraysbury, where the requirements in regard to the waterway made the mid-stream piers too narrow to constitute a fixed support for the middle arch of 50 ft. span. To increase the stiffness of the middle pier the whole of the smaller end span was designed as a closed stiff frame with a solid bottom slab connecting the end pier with the middle pier. Although to all intents and purposes the end arches might be considered as fixed in the piers, this was not the case with the middle arch, the reactions of which on the closed end frame induced certain deflections, more particularly horizontal and angular, which had to be calculated and taken into account in order to determine the final stresses in the middle arch. A similar design, the Langenzug Bridge, was described in this journal in May, 1911; in this bridge the same conditions prevailed with the exception of the bottom slab being piled instead of resting on the ground. *Figs.* 3 and 4 show a section and elevation of this bridge, the spans being 60 ft. and 30 ft. respectively.

A different type of arch bridge is shown in *Figs.* 5, 6, and 7, where the difficulty was due to the abutments being unable to take the horizontal thrust from an arch of about 90 ft. span. For reasons of economy some old piled abutments were to be used, and as the inclination of the old piles was very slight the resistance to thrust was correspondingly small. A number of piles with a strong batter were driven behind the old abutment, and in order to obtain weight enough to make them active as thrust absorbers a cantilever arm was extended behind the arch proper. Even then the piles were unable to take the full thrust from the various conditions of loading, but the cantilever, apart from acting as a loading platform for the skew piles, fulfilled another important object, viz., that of inducing a negative bending moment in the abutment, which again caused a diminution of the thrust to safe limits. In this case, therefore, an abutment which would give way to the ordinary arch action was endowed with a negative thrust, which acted as a set-off to the positive thrust from the arch.

FIG. 4.—LANGENZUG BRIDGE.

FIG. 5.—SCHAARTOR BRIDGE AS COMPLETED.

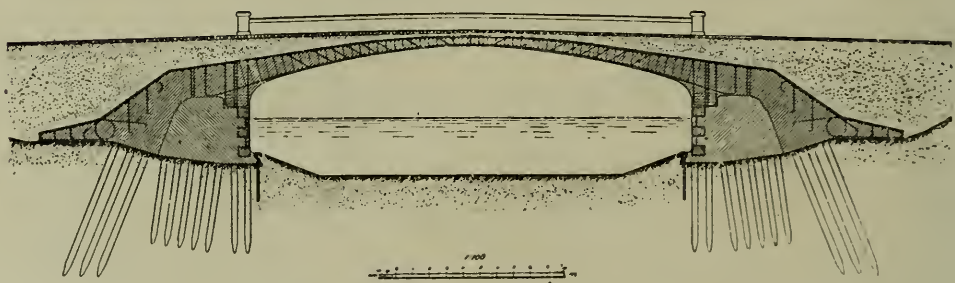


FIG. 6.—SCHAARTOR BRIDGE: SECTION SHOWING OLD MASS CONCRETE FOUNDATION BLOCKS EMBODIED IN THE NEW STRUCTURE.

FIG. 7.—SCHAARTOR BRIDGE UNDER CONSTRUCTION.

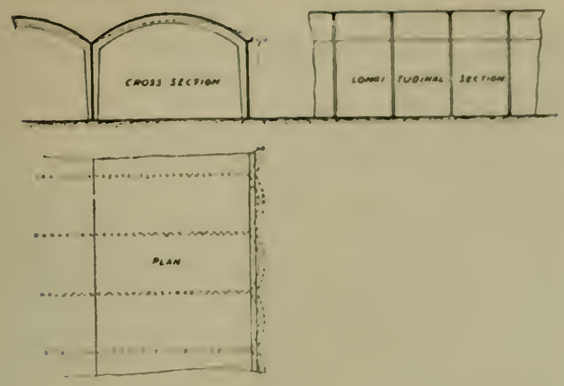


FIG. 8.

As an example of the serious effects of unforeseen movements in the supports of arch structures the following illustration (*Fig.* 8) shows a warehouse that came under the writer's notice some little time ago. The roof of the warehouse is constructed as an arch with about 100 ft. span; the trusses are about 30 ft. apart, and as the slab is only 4 in. thick and consequently cannot span between the trusses, the arch action is relied upon. An arch of 100 ft. span with a thickness of only 4 in. requires, however, very reliable abutments, which do not appear to have been provided, the horizontal thrust being taken by a small eaves beam, which itself is spanning 30 ft. between the trusses. The results of the movements of the supports are shown in dotted lines; the eaves beam bulging out between the trusses has caused the crown of the arch to sag considerably. As the spreading of the haunch flattens the arch this increases the thrust, causing further spreading, so that a vicious circle is established; a temporary relief is afforded by the distributing bars between the trusses, which support the slab suspension-wise.

CONCRETE IN FORTIFICATION WORKS AT HELIGOLAND.

HELIGOLAND is not a large island—it is only about a mile in length and 550 yards in width—and has steep cliffs on all sides. The sole means of access are two stairways cut in the cliffs, and an electric lift.

The massive fortifications include a port capable of holding 150 submarines at once. The 120 cannon of various calibres were placed in much the same positions as on a man-of-war, and the island was provided with a wonderful network of tunnels which gave complete access to every gun.

Concrete has been used in very large quantities for the protection of the guns, both mass and reinforced concrete being used.

Two observation posts, one at the north and the other at the south of the island, were connected by means of a tunnel 7 ft. high, the roof of which was formed of reinforced concrete at least 5 ft. thick.

The superstructure of each turret for the 305 mm. guns had three platforms, and a very strong and thick cylinder of reinforced concrete at its base.

The smaller ordnance was protected by concrete 10 ft. thick, the same thickness being adopted for all parts of the fortress subjected to direct fire.

The greater part of the submarine harbour was covered so as to make it invisible to an attacking force. The portions of the jetty built at a small depth were composed of large blocks of concrete, the deeper portions were built on caissons of concrete, each 83 ft. long, 33 ft. wide and 33 ft. high. They were built on the shore, floated to the proposed site and there sunk by filling them with concrete.

The destruction of the fortifications is now proceeding. The concrete works and the tunnels are being destroyed by dynamite, the machinery is crushed to pieces and the cannon are cut up by means of oxy-acetylene lamps. The port will be completely destroyed, but it is estimated that two years will be required for its destruction. Breaches are also being made in the various parts of the works most exposed to the sea, so that the latter may aid in the destruction.—*Le Génie Civil.*

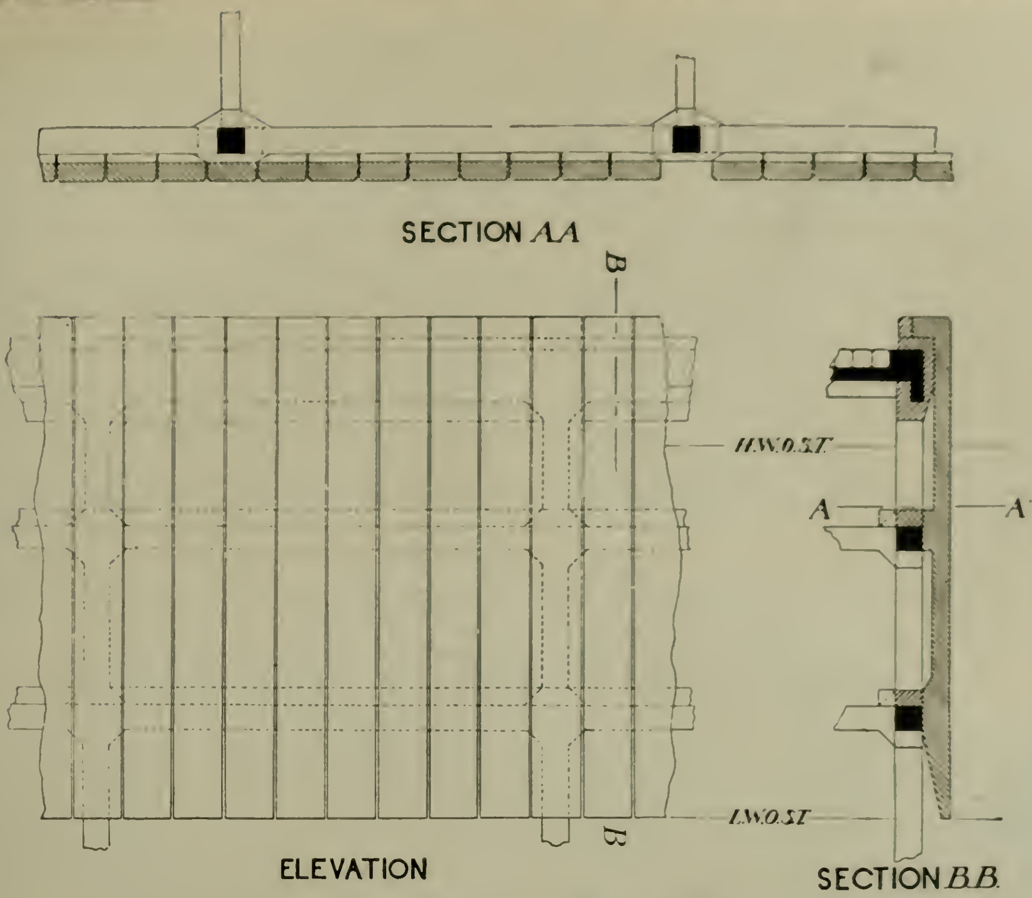
REINFORCED CONCRETE IN HARBOUR CONSTRUCTION.

By GOWER PIMM, A.M.Inst.C.E., M.C.I.

EARLY in 1915 the Newlyn Pier and Harbour Commissioners decided to carry out certain improvements and repairs to the North Pier at Newlyn Harbour, Cornwall. The original mass-concrete pier had been widened in 1908 by the addition of an openwork ferro-concrete extension on the harbour side, and the new work consisted principally in the construction of a continuous reinforced concrete facing to this openwork structure, extending from deck level down to approximately low-water level. Tenders were invited for the execution of the work to the detailed designs of the parties tendering, and in accordance with the general specification of Messrs. Douglass, Lewis & Douglass, the engineers to the Harbour Commissioners, and from the schemes submitted that of the writer was selected.

Before putting forward the final scheme many considerations had to be weighed, particularly the necessity for reducing to a minimum the obstruction of the pier during the execution of the work, and as it afterwards proved the consequences would have been even more

REINFORCED CONCRETE AT NEWLYN HARBOUR.



Reinforced Concrete at Newlyn Harbour.

serious than was anticipated if the work had not been designed with special regard to this point.

The scheme, as will be seen from reference to the photograph and drawing, consisted in the formation of a front longitudinal beam of great strength and rigidity at deck level, and suspended pre-cast slabs forming the continuous facing. The slabs, about 22 ft. long by 2 ft. wide, and weighing 56 cwt., were made face downwards on the deck of the pier. A heavily-reinforced nib was provided for the purpose of hanging the slab on the beam, this reinforcement being left projecting beyond the nib and incorporated with the reinforcement of the coaming, the back portion of which was moulded *in situ*, the front being formed by the head of the slabs. The vertical reinforcement of the coaming was passed through holes drilled in the deck slab and round the existing front longitudinal beam and formed the shear reinforcement of the new beam, which, as will be seen, completely envelops the old one. In addition to the top fixing described, hooked bars were left projecting from the back of the slabs just above the points of contact with the upper and lower bracings of the existing structure, upon which additional bracings were moulded *in situ*, incorporating the bars projecting from the slabs. Each slab is therefore effectively tied at three points to the old work, greatly strengthening the latter and depending upon it only in so far as the bearing strength of the piles is concerned. The ability of the piles to support the additional weight was considered to be ample, but in order to anticipate the possibility of settlement of an individual pile the whole of the new facework was designed in such a way as to possess considerable strength as a beam, and it is probable that if one, two, or even three adjacent piles were removed or undermined the facework would not be affected, but would span the gap satisfactorily.

The original intention had been to make each slab as near as possible to its final position and lower it into place from the deck, but owing to the subsequent abnormal use of the pier during the execution of the work it became necessary to mould the slabs in such places as were available and to lower them in batches of nine on to a pontoon upon which a crane was rigged for the purpose of handling and setting them.

The slabs were made with chamfered edges, and were set with open joints about 1 in. wide in order to provide a vent for the air imprisoned behind them by the rising tide. In addition, at intervals along the pier, single slabs were omitted and iron ladders fixed in the recesses so formed. Mooring rings and cast-iron bollards were fixed to the top of the coaming. The length of pier treated was about 820 ft. The reinforcement throughout consists of mild-steel indented bars.

An important point in the design of reinforced concrete piers and landing stages is the sloping-back, or other protection from the impact of vessels, of the front longitudinal beam below the point at which it ceases to receive lateral support from the transverse beams. The lateral bending, which otherwise takes place, and the resulting longitudinal cracks are a fruitful source of trouble in marine work, and have perhaps contributed more than any other factor to the prejudice which still exists in some quarters against reinforced concrete for works of this nature. In the present case, therefore, notwithstanding the great strength of the beam and the protection afforded by the facing, the principle was adopted of limiting the depth subject to impact to the depth of the transverse beams.

CONCRETE BUILDING AT VALPARAISO.

Residences aud Shops in Concrete, at Valparaiso.

The building illustrated is a block of rental property being built for the Co-operative Annuity Society of Valparaiso. This terrace, of which the block shown is the commencement, is destined to occupy the whole of one side of the Avenida Ecuador, and is being built in sections.

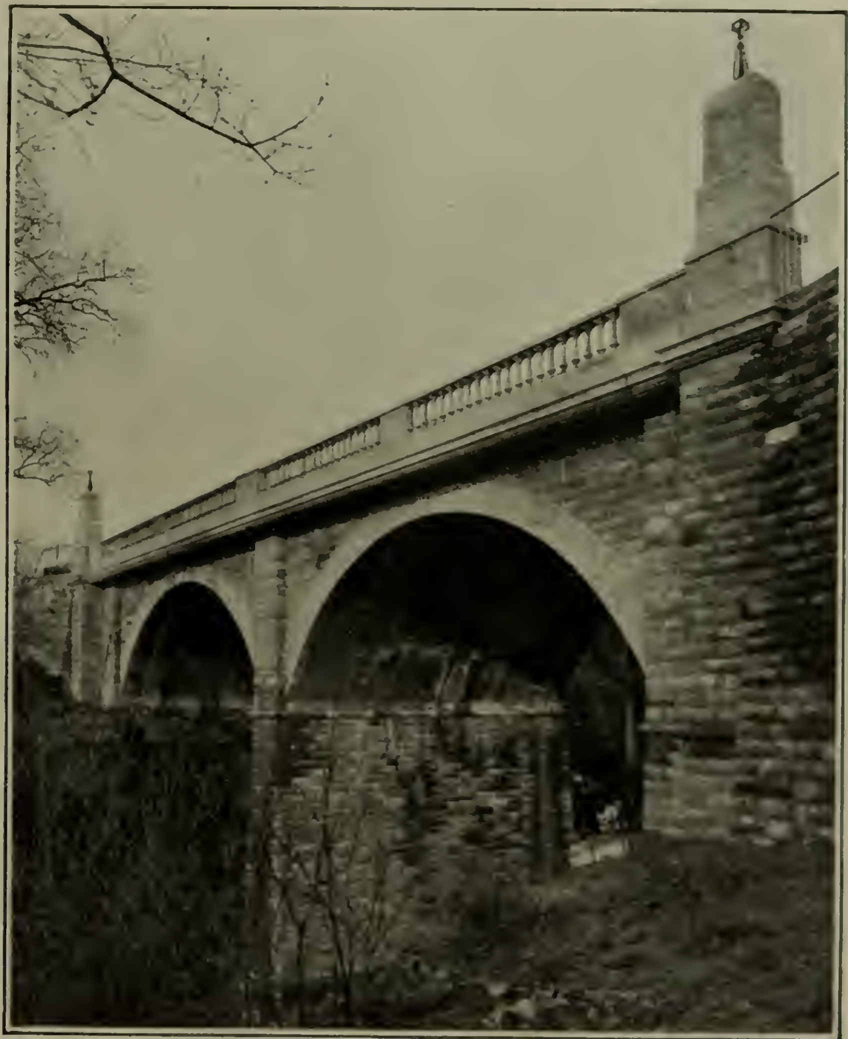
The block in course of construction consists of twenty residences with twelve shops underneath. The whole construction is of reinforced concrete, and is built on the granite rock of the hill, which had to be blasted and quarried for the foundations. The five stories are constructed entirely of fire-resisting material with the exception of the doors and windows and a portion of the roof. In the concrete floors and walls a considerable amount of "B.R.C. Fabric No. 10" has been used for reinforcement.

In this building 1,000,000 dollars have already been invested, in addition to 200,000 dollars representing the cost of the site. The Society has now purchased more land on the opposite side of the street, on which another million pesos are to be spent in the construction of thirty private residences, also of reinforced concrete. In addition, plans are already being prepared for the building of a skyscraper on a site belonging to the same owners facing Plaza Victoria.

The architect of the building in progress is Mr. Arturo Sthandier, and the contractors are Messrs. Franke, Julian & Co.

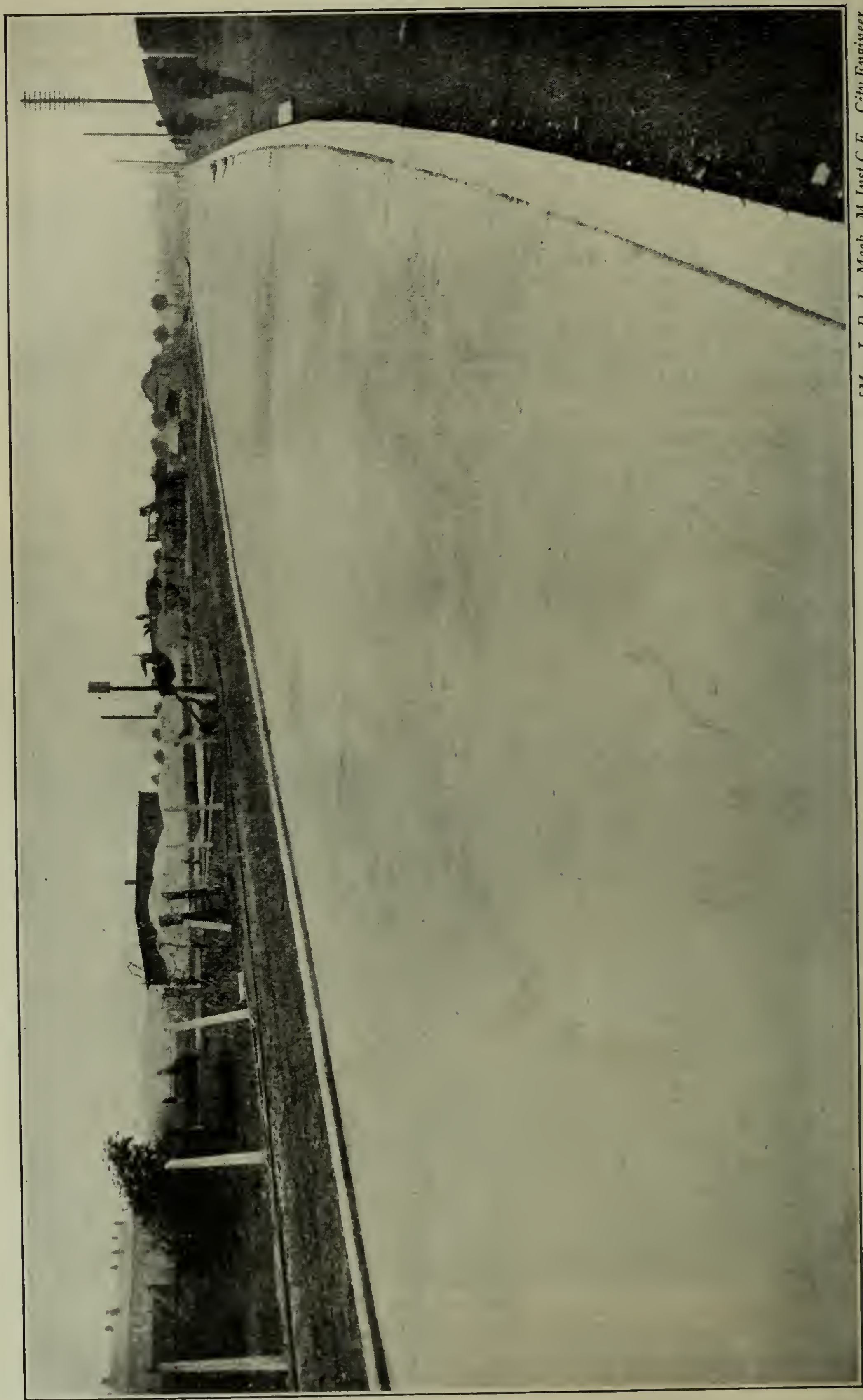
REINFORCED CONCRETE BRIDGE AT HASTINGS.

The bridge illustrated on this page has been built to the design and calculations, and under the supervision, of Mr. Philip H. Palmer, M.Inst.C.E., Hastings Borough Engineer, and carries one of the new arterial roads across a glen near that town. The bridge, which is 40 ft. wide on the roadway, has two spans of 45 ft. each, and is 81 ft. from the bed of the stream to the road level. It is constructed of reinforced concrete and faced with concrete blocks made on the site. The reinforcement consists of heavy section expanded metal and steel rods where necessary. The total cost of the bridge is stated to be £12,000, in spite of the fact that the whole of the materials had to be hauled a distance of four miles from the nearest railway station. The only parts which were not constructed on the spot were the parapet and balusters. The bridge was tested with rolling and stationary loads of 24 tons without any signs of deflection, and we are informed there is not a crack in the structure. The blocks used for the facing were all made on a " Winget " machine.



[*Mr. P. H. Palmer, M.Inst.C.E., Borough Engineer.*

Reinforced Concrete Bridge at Hastings.



[Mr. J. B. L. Meek, M.Inst.C.E., City Engineer.

REINFORCED CONCRETE ROAD AT MANCHESTER. (See p. 539.)

CONCRETE ROADS AT MANCHESTER.

In view of the large number of all-concrete roads now being built in this country, the following particulars describing the various processes employed upon the construction of this type of road at Manchester by the Manchester Corporation, under the direction of Mr. J. B. L. Meek, M.Inst.C.E., City Engineer, are of interest.

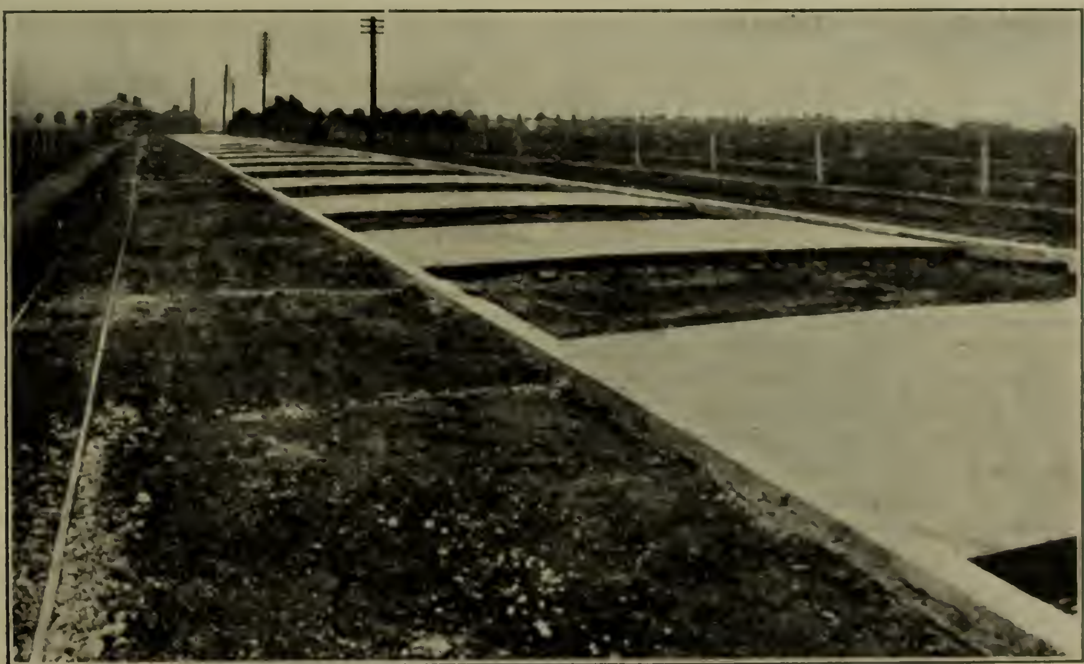
Previous to the commencement of the work the foundation was excavated parallel to the finished contour of the road-surface. Loose places in the foundation were made good with dry filling and wet places drained, so that the foundation might be as dry and solid as possible. So far as possible the natural foundation was not exposed to the action of damp and wet before being covered up. On the natural foundation a layer of clean clinkers or ashes has been placed and rolled and consolidated to a depth of 3 in. by a steam-roller. Before the concreting commenced the foundation was well watered.

The thickness of the concrete slab is 7 in., composed of two layers. The bottom layer is 5 in. in thickness, composed of 1½ in. to ¼ in. gauge stone, sand below ¼ in. gauge, and Portland cement complying with the British Standard Specification; the stone for this layer is good hard local stone. The upper layer is 2 in. in thickness composed of ¾ in. to ¼ in. gauge approved granite, granite or other approved sand below ¼ in. gauge, and Portland cement.

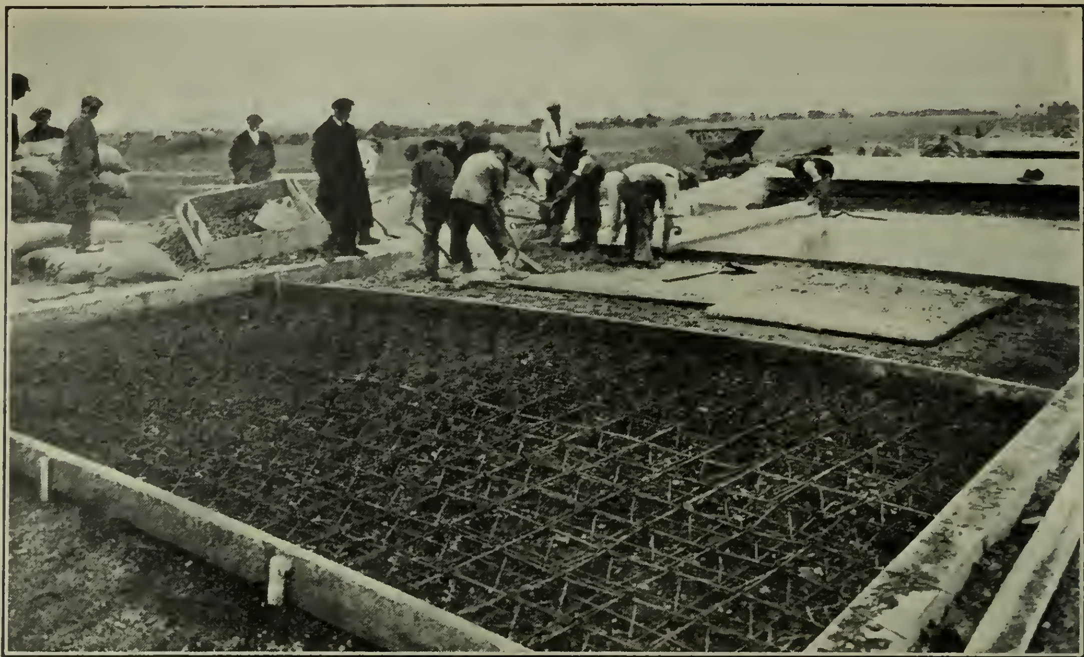
The proportion of the concrete for the bottom layer is 5 parts stone, 2½ sand, and 1 cement; and the proportion for the top layer is 2 of granite, 1 sand, and 1 cement. Concrete cut out of the finished road for the whole thickness, after being a fortnight in a dry room, did not absorb more than 3 to 4 per cent. of its weight of water after being immersed for eighteen hours. Great care has been taken in proportioning, and to ensure that the materials comply with the sizes specified.

All materials are first approved by the City Engineer before use, and the sand is tested for organic matter before use in the work; the cement is also tested to see if it is in accordance with the British Standard Specification. Any sand containing organic matter, or cement not complying with the Specification, is rejected. The sand for the lower layer is reasonably sharp, and the sand or granite dust for the upper layer is of good sharp quality.

All concrete is placed in position as



Finished reinforced bays with intervening spaces to be concreted.
Reinforced Concrete Road at Manchester.



Interlocked Double-Layer Reinforcement in position.
REINFORCED CONCRETE ROAD AT MANCHESTER.

soon as possible after mixing, in order to avoid the initial set being broken through by moving the concrete.

The concrete is laid in alternate bays of a suitable length, each bay finished with a straight joint, and bays are not left unfinished at the end of the day's work or at meal hours. When the bays have sufficiently set, the intermediate spaces are filled in. In mixing concrete only sufficient water is used to bring it to such a consistency that it can be easily put into position, and over-wetting is avoided. In concreting the bays, the lower layer is placed first; the top layer follows immediately after and before the lower layer has had time to set. The two layers are kept going as nearly as possible simultaneously, but in no case is the upper layer deposited more than twenty minutes after the lower layer has been deposited, the object being to obtain a homogeneous mass of concrete throughout each bay.

The surface of the concrete is finished off to the required levels and falls with a wooden or steel-shod template, and no trowelling is necessary. The surface is kept thoroughly damp by frequently watering for one week after it has been put into position. No traffic is allowed on the concrete for at least a month after it has been put into position or until such time as the concrete is fit to bear traffic. This time varies in accordance with the weather conditions, but in all cases at least one month is allowed to elapse between the placing of the concrete and allowing the traffic on the work.

As the natural foundation has not sufficient strength to withstand the load transmitted to it through the 7 in. of concrete, reinforcement is used; and where trenches have been recently excavated in the foundation for pipes or other services reinforcement is to be placed in the concrete over the trenches.

The reinforcement used is the "Walker-Weston" interlocked double-layer reinforcement supplied by the Walker-Weston Co., Ltd., 7, Wormwood Street, E.C.2, which provides for tensile, shear, and contraflexure stresses. The width of the carriageway between the kerbs is 24 ft., and, as the road is laid in alternate bays, double-layer reinforcement is supplied in mats about 24 ft. by 12 ft. 6 in., so that they drop in between the kerbs. A bay of 12 ft. 6 in. is concreted and a space of 12 ft. 6 in. left, and when the concrete has set in the adjacent bays the reinforcing mats are dropped in and the intervening bays concreted. The reinforcement is laid at right angles to the kerb, and the concrete tamped around the bars of the reinforcement. The reinforcement is protected by a 2-in. thickness of concrete at the top, and approximately 1 in. at the bottom.

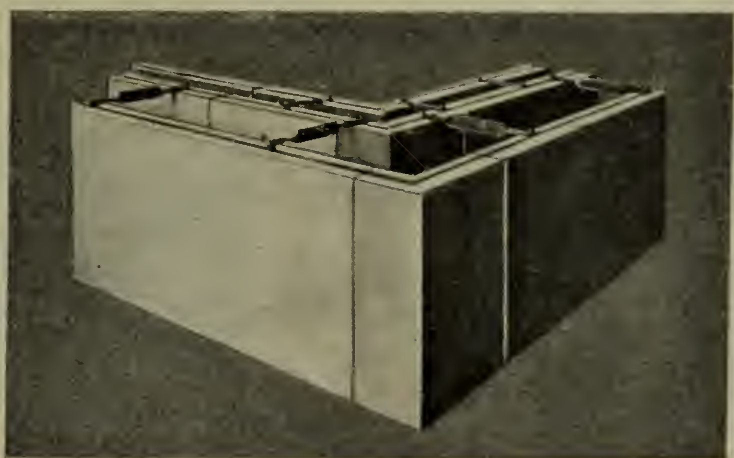
NEW METHOD OF CONCRETE CONSTRUCTION.

We recently had an opportunity of seeing a demonstration of a form of concrete building embodying features which appear to have possibilities not only of reducing the cost of building, but also of making the concrete house attractive without any appreciable extra cost. The chief idea of this system (the "Tileform") is to eliminate the cost of shuttering by making the formwork an integral part of the building where solid walls are required, and to provide an easily-made and easily-handled slab for the erection of cavity walls in which in no place does the concrete extend right through the walls; in the latter case, the tiles, which are strong enough to support floor joists without filling, are held apart to the required distance by metal ties.

The uses of the tiles are clearly shown in the accompanying illustrations. They are readily adapted to any form of construction, and may be made to any size. The ordinary measurements, however, have a minimum thickness of 2 in., a height of 12 in., and a length of 21 in. At corners angle-tiles are used which have one face twice as long as the other, so as to break joint when superimposed over one another. The tiles are made on a simple hand-operated mould composed of metal plates, with the end pieces so designed that tongues and grooves are formed to strengthen the joint; and by the insertion of moulded pieces of wood or metal any desired shape may be obtained if ornamentation or architectural features be required.

At a time, however, when the æsthetic side of the use of concrete for building purposes is so much under discussion the tiles used in this system have much of interest. They are composed of Portland cement and sand, without the addition of stone, gravel, or other aggregate, and are very dense and impermeable. The mixture is consolidated in the moulds by vertical rodding, which forces fine particles of semi-dry mixture into every crevice of the mould. Immediately after they leave the moulds the seasoning of the tiles commences, by the application of water from sprinklers; and later they are stacked closely together and frequently soaked until they are thoroughly cured. The result is an excellent surface, comparable with stone, and with the addition of colouring matter or solutions a very complete range of shades is produced, by a judicious selection from which it should be possible to produce a pleasant façade.

For internal decoration, also, concrete tiles with a smooth surface and an attractive colour have considerable possibilities in the direction of cheapening the cost of building, for, providing a cavity be left in order to prevent the danger of condensation, there seems no reason whatever why such a concrete surface should not take the place of lath and plaster. Samples of "Tileforms" in various colours have a very close resemblance to a distempered wall, with the additional advantage that the colour is an integral part of the wall and does



"Tileform" Construction.

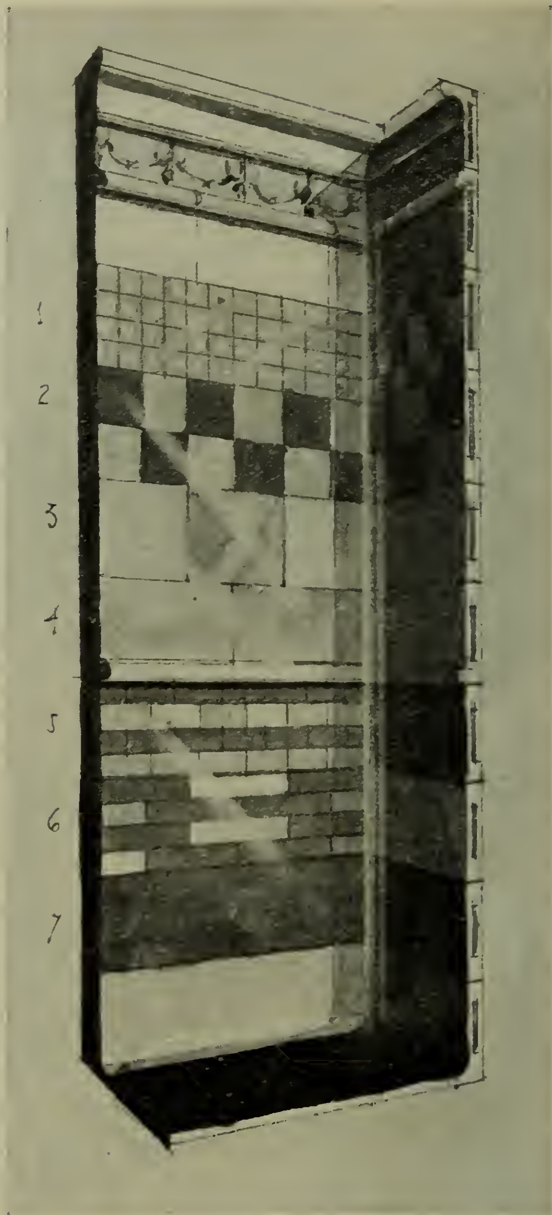
not require frequent renewal as does distemper. The surface of these concrete tiles also takes paint and enamel well, and thus treated could be used to take the place of glazed earthenware tiles with a saving in cost, for such a surface would not be a decoration added to the wall at extra expense, but the wall itself enamelled to resemble tiling at the cost of paint only.

Where the tiles are thus used in interiors, they may be shaped to take the place of mouldings around doorways, skirtings, window frames, etc., thereby eliminating much of the woodwork, and adding to the fire-resisting properties of a building. Partition walls in this system are built up of single tiles 2 in. in thickness, or where sound-proof walls are required double walls may be used with a cavity between.

The smoothness of these tiles lends itself well to the application of decoration, in imitation of carving or plaster work, at the one operation of making the tile, and this ornamentation can, of course, in so plastic a material be obtained in infinite variety, to which further interest may be given by colour.

The system is not confined to the erection of plain walling and decorative features, however, for attention has also been given to the construction of piers and columns, both round and square, by the use of these tiles; for solid piers, the tiles are moulded to the required shape and size, and after being placed in position one above the other the core is filled in with concrete, reinforced if necessary.

Further particulars regarding this system may be obtained from Messrs. Tileform, 11, Hanover Square, London, W.1.



"Tileforms" for Interiors.

"Tileforms" in Decorative Work.

BOOK REVIEW.

Building Contracts. By Edwin J. Evans. London: Chapman & Hall, Ltd. 504 + xviii pp. Price 10s. 6d. net.

This volume forms one of "The Directly-Useful Technical Series" which are prepared to combine the necessary amount of scientific explanation with the practical application of the subject dealt with, and thus they will appeal to all classes of technical readers. Sir Charles T. Ruthen, Director-General of Housing, has written the foreword, and in this he mentions that the building industry in pre-war days was the third largest industry in the British Isles; it is also one of great complexity, and all good contracts should provide that the true interests of the building owner, architect, manufacturer, building contractor, and operative are protected. The contents of the book are: Administration of Contracts, Office Management and General Notes, Book-Keeping, etc., Trade Memoranda, and Plant Lists, but these headings do not fully indicate the comprehensive nature of the treatise, because each of the four parts is divided into several chapters, the total number of which is seventy.

In the introduction the author gives some general advice on the methods of becoming efficient, and there is no doubt that any student who will foster and practise the principal characteristics specified must become successful if there is any reward for virtue in this world!

It is impossible to deal adequately with all the matter contained in the book in a short review, but, generally speaking, the author puts forward a mass of information which will prove extremely useful to the contractor; at the same time there is a good deal which could be omitted without detriment. The remarks on the question of ensuring that the contract will be a satisfactory one to the contractor before he agrees to undertake the work suggest an expenditure of time and trouble which would never be undertaken by the average contractor, and the chapter under the heading of "The Architect" gives the impression that this gentleman must be humoured, supported, prompted, and generally looked after by the contractor if the work is to be completed without serious trouble to all parties concerned.

In dealing with the methods of arranging contracts no mention is made of that form in which the contractor is paid the prime cost plus a fixed lump sum as profit, although this method has been often applied.

We should have expected the author to have dealt more fully with the use of modern appliances in the execution of the work, as this is surely one of the most important factors in the successful administration of contracts; in the case of haulage or transport the notes are confined to horse-drawn vehicles, whereas petrol and steam-driven wagons are much more economical types where the works are at all extensive. The memoranda for contractors contained in the last section are an extremely useful addition, as the tables and notes generally will afford a ready reference for particulars that are frequently required.

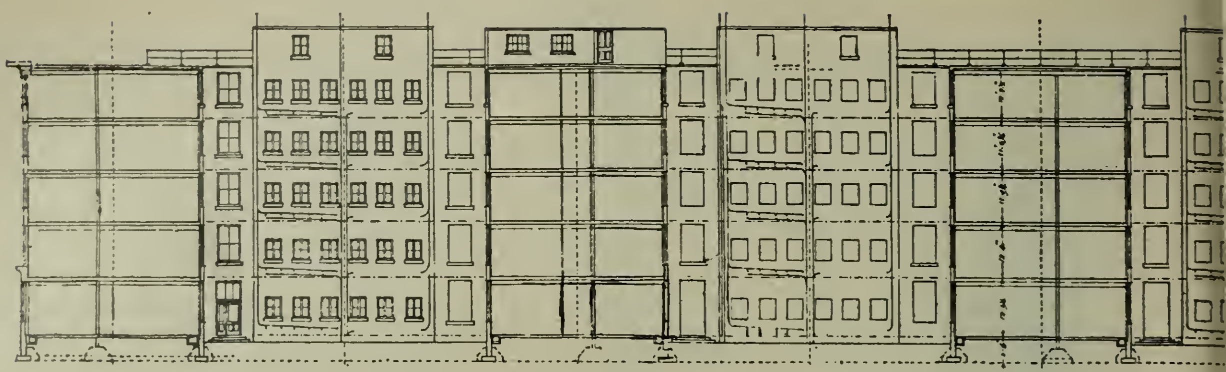
We can recommend the book as one that contains much which is useful and interesting, and the contractor who is guided by the leading principles put forward by the author will contribute his share towards a successful and harmonious contract.—A. L.

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

QUESTION.—I would be glad if you would supply the following information: Is cement grout a good means of protecting steelwork, and, if so, should the steelwork be first painted, and how should the grout be mixed?

A. C.

ANSWER.—Cement grout is not good for protecting steelwork, because one has to mix more water than is necessary for the best mixture, and the water evaporates, leaving the skin of grout porous, thus letting in the air. If grout is used, the grout is made by mixing cement and water together until it has the consistency of thin porridge. The steel should not be painted before putting on the grout.



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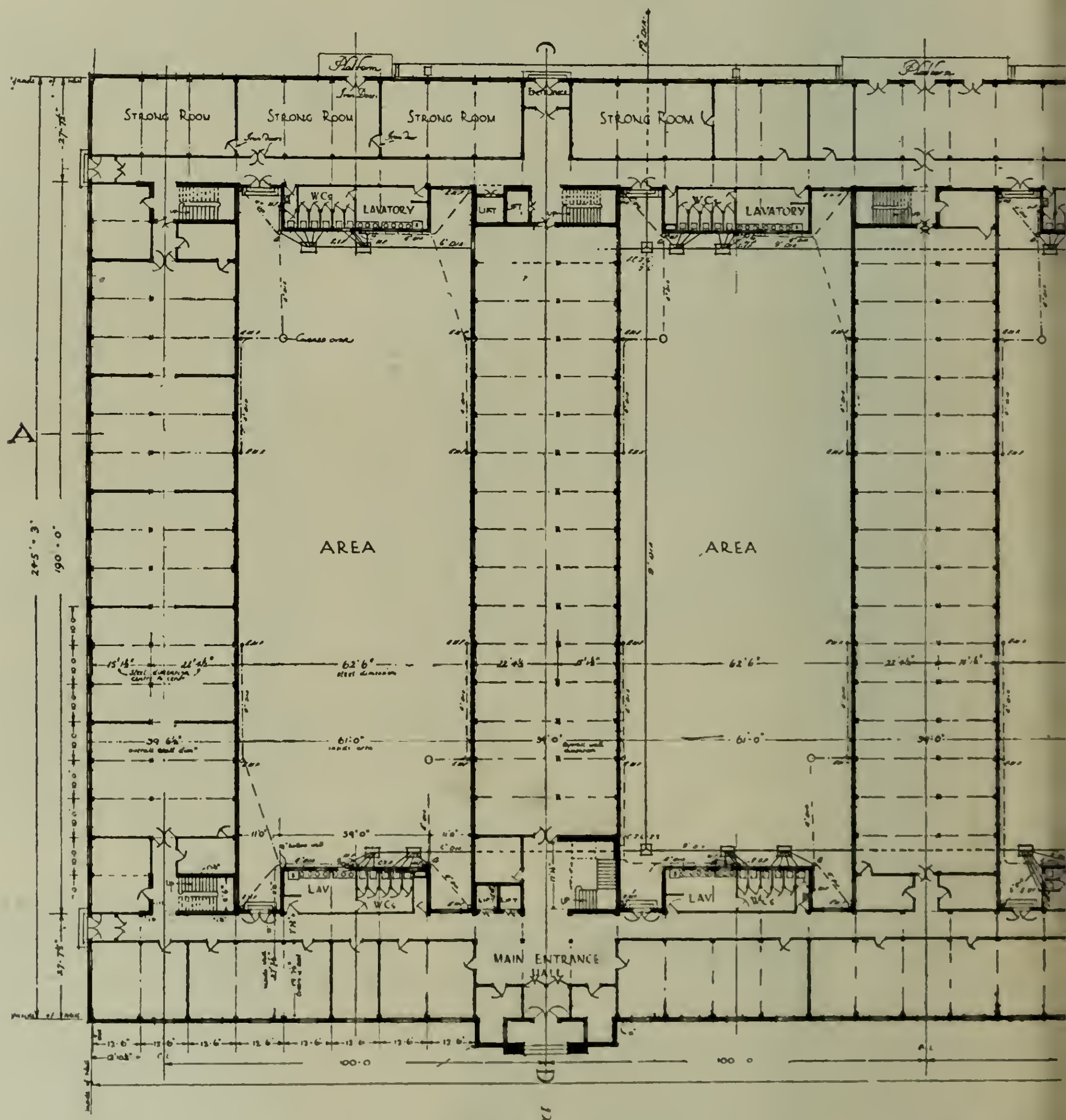

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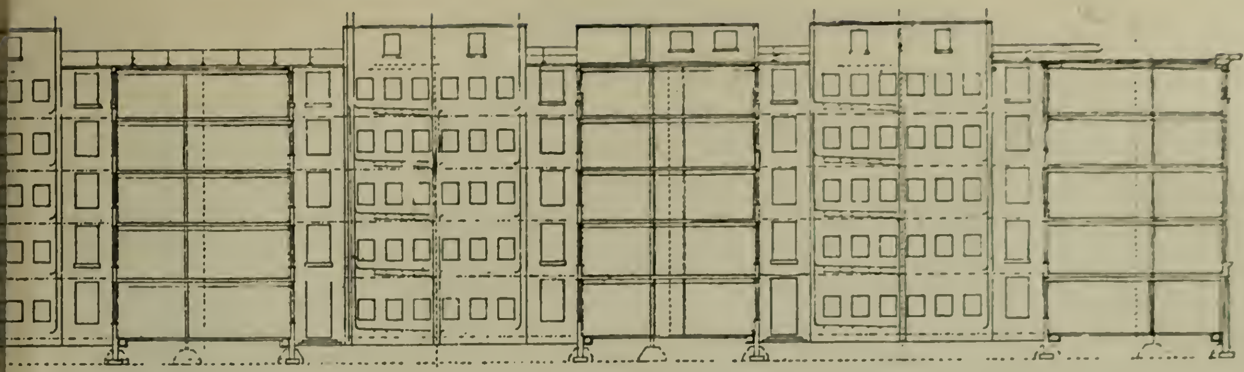
THE NEW PENSIONS



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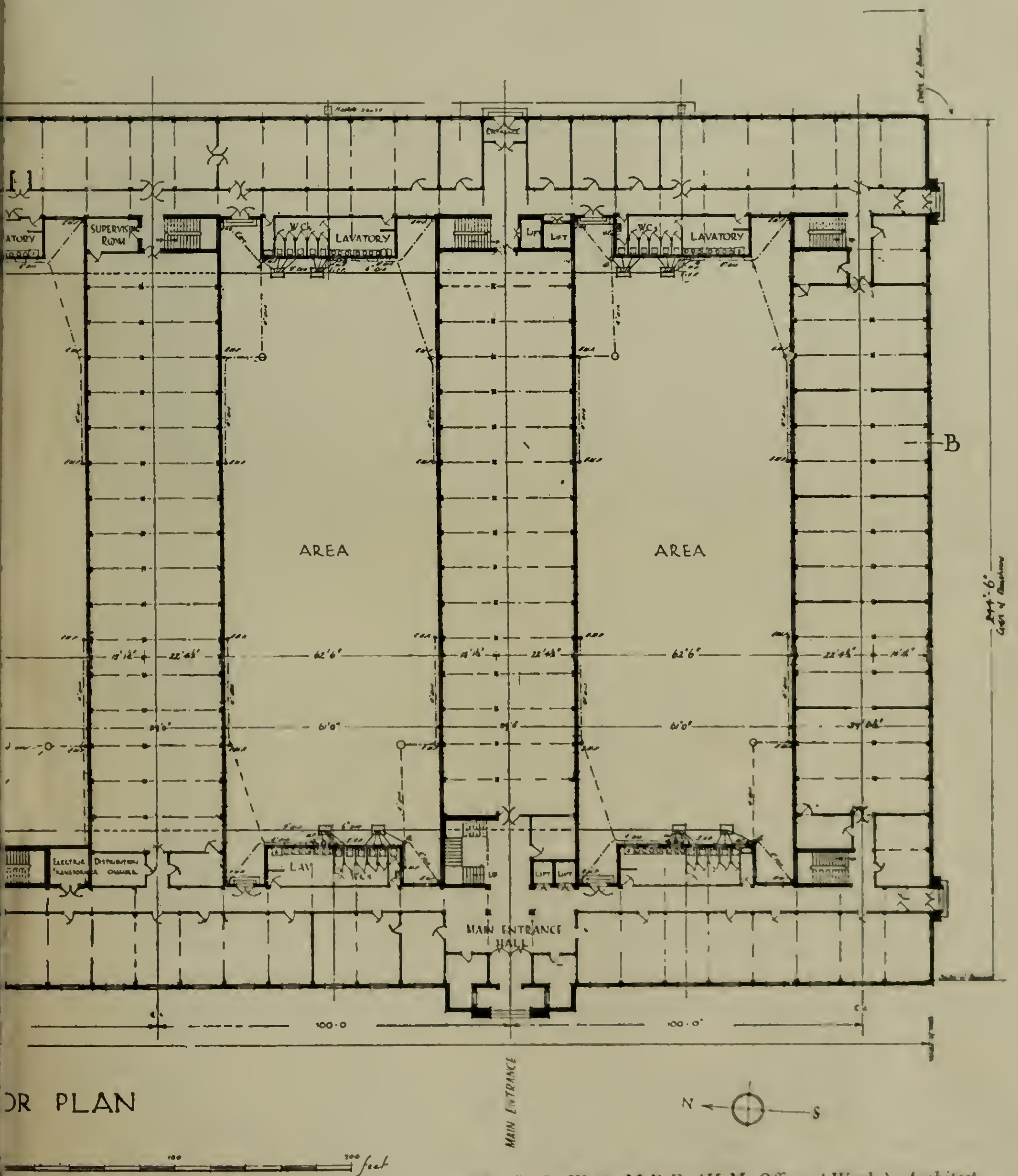


OR PLAN

n inch.

[*Mr. J. G. West, M.B.E. (H.M. Office of Works), Architect.*

NG, ACTON. (*See p.* 505.)

CORRESPONDENCE.

REINFORCEMENT IN CONCRETE.

SIR,—Dr. Faber's reply in the last issue of *Concrete and Constructional Engineering* to Mr. Shelf's argument in favour of the use of high-tensile steel appears thoroughly conclusive so far as the latter's attack on "theoretical engineers" is concerned, but otherwise is far from complete. It is obvious that Mr. Shelf has based his conclusion on a rather elementary mistake, which did not require much effort on the part of Dr. Faber to rectify, but apparently Mr. Shelf's difficulty is of larger dimensions—it is not so much objection to wrong theory as to theory right or wrong. There is really no such divorce between theory and practice as the writer of the letter, in common with many others, appears to think. A practical engineer is really not one who is ignorant of, or indifferent to, the theory underlying the design, but one who bases his design on a complete and correct knowledge of the laws of Nature concerned, and who is able to apply such knowledge in a practical manner. Mr. Shelf is apparently unaware of the fact that theory in general is simply accumulative practice, in this case derived from numerous experiments on the materials. Indeed, it is perhaps not too much to say that had it not been for the much despised theory reinforced concrete would never have attained the position it now occupies among building materials.

In the present instance, however, there is something in the argument set out by Mr. Shelf, in spite of the reason given by him. Is it not a fact that notwithstanding the raising of the neutral axis there *is* a saving in the cost if high-tensile steel be used instead of ordinary mild steel? The real objection to its use, however, is the fact (which Dr. Faber has not alluded to) that the increased working stress in the steel necessarily involves an increased stress in the adjacent concrete (theory again), and that the practical engineer would not recommend the use of high-tensile steel in most cases on the ground that such increased tensile stresses in the concrete referred to would cause larger or more numerous cracks, or both, and these would increase the liability of the steel to rust and expand, and so tend to disintegrate the concrete, and that the running of such a risk would by no means be justified by the small saving in cost, and that this is a very practical objection indeed. It is scarcely necessary to point out that this objection obtains particularly in the case of structures in salt water whatever estimate is placed on its value.

W. Y. CHAMBERLAIN.

Engineers' Department,
Harbour Office, Belfast.

SIR,—On page 485 of your July issue I see an interesting confliction of opinion by two writers on the question of reinforcement. Curious as it may seem, I agree with both the correspondents, but I think Mr. Shelf would have done well to have written a little more to explain what I understand to be his objection to want of economy in mathematical precision. A great many schemes are carried out quite correctly by mathematical design, but the want of a good knowledge of all the details of construction—such as costs and local difficulties in carrying out these mathematical tactics on the site of works, often result in the work costing far more than would be the case of more simple construction—and the work would be quite as efficient.

It was just the same in the early days of iron girder design. At first they were simple; then the high standard of calculations set in, with the result of most extraordinary shapes and complications of what might have been quite simple girders. Any engineer can note the change in ordinary short span railway girders from those adopted in middle times, nearly all the girders now being of the simple plate girder type.

I constantly see in reinforced work this tendency to queer design, and I fear these designs are too often taken out without due consideration of the great cost of still more queer shuttering, etc., and very awkward places for men to work in—in fact, in some cases the designs cannot be carried out in practice!

E. F. W. GRIMSHAW,
Member of the Concrete Institute.

REINFORCED CONCRETE ROADS.

Sir,—The correspondence by Mr. J. F. Butler, of the British Reinforced Concrete Engineering Co., Ltd., and Mr. W. S. Pegg, of Messrs. Brown & Tawse, Ltd., is very interesting, as also is the reference to a longitudinal crack in the centre of a concrete road by Mr. J. H. Walker.

As an inspector of reinforced concrete roads, both in this country and abroad, I venture to submit a few brief points gained by practical experience. The time has not arrived for the standardisation of reinforced concrete roads, as in this country they are as yet in their infancy. With standardisation experimental initiative is immediately stopped, and in consequence progress is hindered. Let the various reinforced concrete specialists experiment until we get perfection ; then is the time to standardise, but not before. Experience has taught me that the longitudinal type mesh reinforcement is premier of all others for road work, and the most suitable for the fast-moving and heavy traffic of to-day. The longitudinal mesh reinforcement follows the line of travel, relieving all tensile stresses, both longitudinally and transversely.

With reference to the longitudinal crack in the centre of the road, my experience points to the conclusion that there must have been a longitudinal joint, and that the road was laid down half at a time to allow traffic to pass through the other half, and that there was a certain amount of carelessness in the carrying out of the work.

Mr. W. S. Pegg speaks of a committee of experts to decide certain points. The only expert required is the man in charge of the work, who should have a sound knowledge of concreting before being placed in his position of authority. He should be conversant with the qualities of cement, understand the grading of various aggregates, have a keen knowledge of mixing with the minimum quantity of water, of placing concrete correctly, be able to certify the time of evaporation and initial setting under all atmospheric conditions, and to know how to protect newly-laid concrete from frost, rain, or heat. For Mr. Pegg's information, I answer his six points :—(1) Decided by the choice of mesh ; (2) Longitudinal ; (3) 2 in. from the underside of concrete ; (4) Not necessary ; (5) Not necessary in this country ; (6) Continuous concreting for the day ; men relieved at meal hours.

One of the most perfect reinforced concrete roads in this country is the Bristol–Avonmouth road, of which I was the inspector. The reinforcement used was the longitudinal type, and cracks are nil.

In conclusion, let us get on, each in his own way, experimenting and improving until we have the perfect reinforced concrete road to meet modern requirements.

Del-Tonkin.

Market Drayton.

CONCRETE RAILWAY TRUCKS.

In order to ascertain the resistance of concrete railway trucks to sudden blows, a buffer, or "stop," was built of concrete, of such a design that the essential part was the same shape and size as the front third of the truck body. This buffer was then tested by running wagons against it at various speeds. As a result of the tests the Heidelberg-Mannheim-Stuttgart Cement Works had a 20-ton coal truck built of reinforced concrete. This truck has been in regular use for 1½ years, and has given no trouble whatever. The Fuchs' Wagon Works at Heidelberg built a 15-ton truck at about the same time ; this has been tested in many ways, with completely satisfactory results. The total weight of these trucks is greater than that of iron trucks of the same capacity, but this may eventually be reduced. Experiments with very porous concrete have not proved satisfactory, and the use of this material for trucks cannot be recommended. The lower cost of repairs and the absence of rusting make the concrete wagons cheaper in the end than those made of iron. Concrete railway trucks are well worth further consideration and development.—*Tonindustrie Zeitung.*

WHAT IS THE USE OF THE MODULAR RATIO?

The following is a report of the discussion on the paper on "What is the Use of the Modular Ratio?" read by Mr. H. Kempton Dyson before the Concrete Institute, an abstract of which has been given in our last three issues:

Mr. E. Fiander Etchells (President), who occupied the chair, referred to experiments by Dr. Faber with regard to shearing in beams. Dr. Faber had put forward a theory and carried out tests, and had got very near to the breaking results. His actual method was to put down the safe working stress load on a beam, and then find the ultimate breaking load on the machine. His safety factors, by his theory, got near to 4 every time, whilst by alternative methods the safety factors varied greatly. It would be interesting to see whether Mr. Dyson, with his theory, could calculate the utmost load that beams would stand, and get nearer to the actual result as shown by the machine.

Dr. Oscar Faber said the author had dealt with many subjects, but in his opinion, his real points would not bear discussion for a moment. With regard to plasticity, for example, that mild steel and other materials had their yield point was no new thing, and yet the straight line law had been used invariably in calculations under working stresses. The lecturer had referred to monolithic structure calculations, and had said that although they had found those calculations very useful it must be remembered that the materials of which practical structures were composed were not ideally elastic bodies. They had remembered those things, but they were designing structures to act within working stresses, and within working stresses the structures they were designing were practically ideally elastic bodies; both concrete and steel, within working stresses, were within 1 per cent. ideally elastic bodies, and if calculations and formulae could be got accurate within 1 per cent., they were doing very well. He hoped to show that Mr. Dyson's formulae were not within 100 per cent. in some places. The author had said that the ordinary formula for the strength of reinforced concrete was empirical. He (the speaker) did not agree. The straight-line law had been tested over and over again by experiments made with extensometers, and it had been found that anywhere within working stresses, and considerably outside working stresses, the beams behaved in close agreement with theoretical assumptions. It was true that in very short beams, where the shear stresses were great in comparison with the bending stresses, these laws were not so accurately followed, but for beams of ordinary ratios of length to depth they were very accurate indeed. The lecturer had made a great point of Talbot's beams, and had pointed out that of two particular beams which had the same amount of steel, in the one case soft and in the other hard, one carried a maximum load of 26,000 lb. and the other 34,300 lb., and asked how that difference was accounted for. As a matter of fact, these were isolated beams, and with the particular concrete he was using, which was particularly poor—1 cement, 3 sand and 6 stone—considerable variations were obtained from isolated tests. In his opinion, that was quite sufficient to explain the disparity between the two results. Certainly on that kind of evidence he would not be prepared to overthrow the years of work which had resulted in bringing modern theorists where they were and take up a totally fresh theory for which there was no scientific basis whatever, except that the lecturer assumed an elliptical stress distribution above the neutral axis, and let the neutral axis go just where it liked. All the tests the lecturer had referred to were tests on rectangular beams with very high percentages of reinforcement—2·76 per cent., and so on. Beams with those percentages were never used in practice, and if the lecturer could not find something in support of his theory except in structures where the percentages were 2·76, for example, about eight times as high as were used in practice, then he did not think the lecturer's theories needed very serious consideration for application to practical structures.

The real point in the paper was the fresh theory for rectangular beams, singly reinforced, and the theory was that the steel was stressed to 16,000 lb. per sq. in. and the concrete to 600 lb. per sq. in., whatever the percentage of the steel. Tests on the subject showed that the ratio between the steel stress and the concrete stress depended on the percentage, whereas in the lecturer's theory it did not. The lecturer indicated that his stress line "had to be stopped when a percentage was reached that got the maximum compressive resistance out of the concrete. Thus, it showed the point at which, if any more steel were inserted, it would give no greater strength—a fact with which most reinforced concrete specialists were familiar." He (the speaker) did not think it was a fact, but that it was wrong. So far as he knew, the more steel that was added the greater was the strength of the beam. After a certain point the additional strength obtained was very small in comparison with the additional steel put in, and certainly a point was reached where it did not pay to use more steel, but nevertheless, if more steel were added certainly more strength was obtained.

With regard to stress distribution, the lecturer considered a stress distribution in which the concrete stress came right down to the steel.

When dealing with heavily-reinforced beams the lecturer's stress distribution in the case of the strongest beams was as shown in *Fig.* 1 (p. 549); in other words, the point where the concrete stress diagram cut the axis was at the level of the steel. But the point where the concrete stress diagram cut the axis was what was usually called the neutral axis, and was the point in the beam where the stress was zero. Yet it was at that very point the lecturer assumed the steel to be stressed to 16,000 lb. per sq. in.; in other words, at that particular layer, when considering the concrete, he took zero stress which involved zero deformation while at exactly the same level he assumed that particular layer in the beam to be stretched sufficiently to produce a stretch of 16,000 lb. per sq. in. in the steel. Those results were absolutely inconsistent and that stress distribution was an impossible one.

The lecturer gave a table showing slabs designed on the ordinary theory and his own theory, and showed that with the ordinary theory a slab not more than 5½ in. thick would carry a certain load which could be determined within 12½ per cent., and with his own theory, 1½ per cent., which was very useful. But, as a matter of fact, if the thickness of the slab were increased by about ½ in. it would be found that

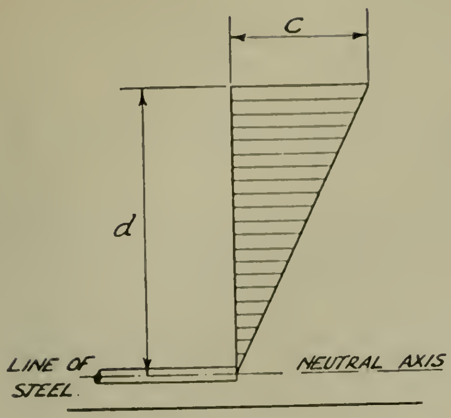


Fig 1.

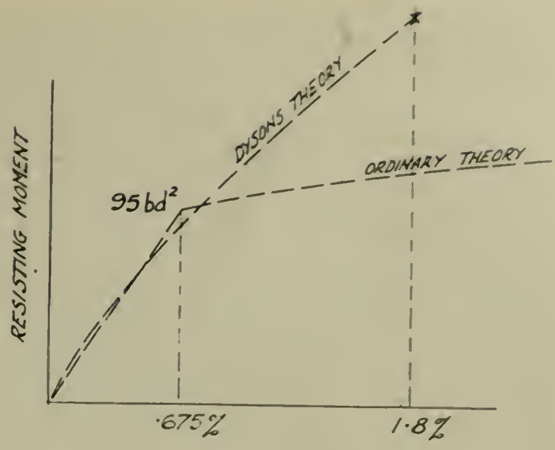


Fig. 2.

the ordinary theory would also work out to about 1½ per cent., and would in addition have theoretical and experimental justification. The lecturer had also stated that his theory gave a factor of safety of 4, but did not prove it. The ordinary curve between resisting moment and percentage was a curve which went up more or less straight to a certain point, and then took a curved form.

He (the speaker) suggested that a curve which gradually increased at a lessening slope with increased percentage was much more likely to be in accordance with facts than a curve which went up to 1·8 per cent. and then went off horizontally. As to factor of safety, in comparing the ordinary theory with actual tests, he had published some tests of his own research work on rectangular slabs some years ago, both singly and doubly reinforced, which gave the following results :—

RESULTS OF EXPERIMENTS OF SINGLY REINFORCED BEAMS.

Percentage of steel.	Safe load calculated by ordinary safety.	The breaking load obtained by experiment.	Factor of safety equals breaking load divided by safe load.
0·234	428 lb.	1,650 lb.	3·8
·467	1,120 ,,	5,330 ,,	4·7
·73	2,180 ,,	7,950 ,,	3·8
1·05	3,180 ,,	13,350 ,,	4·2
1·43	3,530 ,,	14,450 ,,	4·1
1·87	3,900 ,,	18,050 ,,	4·5
2·37	4,230 ,,	19,150 ,,	4·5
	4,450 ,,	21,950 ,,	4·9

It would be seen from the table that over a very wide range of percentages, namely, from 0 up to 2·37, the ordinary theory gave factors of safety which were remarkably consistent and of the right order, namely, 4, since the stresses forming the basis of the calculations for the safe load were taken at one-quarter the ultimate strength of the materials. The lecturer's formula gave very much higher results for all percentages higher than about ·7, and as the experiment showed that the ordinary theory was right it followed that the lecturer's theory, which gave very much higher results, must be wrong.

RESULTS OF EXPERIMENTS OF DOUBLY REINFORCED BEAMS.

Percentage of steel.	Safe load calculated by ordinary theory.	Breaking load obtained by experiment.	Factor of safety equals breaking load divided by safe load.
·467	2,220 lb.	10,600 lb.	4·8
·73	3,330 ,,	12,950 ,,	3·9
1·05	4,620 ,,	18,180 ,,	4·0
1·43	5,500 ,,	20,450 ,,	3·7
1·87	6,400 ,,	31,450 ,,	4·9
2·38	7,400 ,,	33,680 ,,	4·5
2·9	8,400 ,,	41,080 ,,	4·9
3·56	9,600 ,,	38,950 ,,	4·1

The safe loads in the above calculations were obtained by putting the stress in the compression of steel as the stress in the concrete at that distance from the neutral axis multiplied by the modular ratio 15, and it would be seen that over a very wide range of percentages the factor of safety remained practically constant and of the right order throughout the whole range, which was very strong justification indeed of the substantial accuracy of the assumptions made. Here again, as the lecturer's theories admittedly gave a quite different result and the experiments showed that the ordinary theory gave substantially accurate results, it followed that the lecturer's theories were not supported by the experimental evidence. The beams were made by hand, and variations were, therefore, likely to occur, but, subject to those necessary variations the factors of safety were sufficiently uniform, and averaged 4 as near as averages could be expected to go. The compressive strength of the concrete was about 2,400 lb. per sq. in.

The lecturer had pointed out that there was such a thing as shrinkage and yielding of the concrete. That was true, but the modular ratio still had a value. They could make allowance for those two effects. They had the effect of throwing stress on to the steel and taking it off the concrete, but the modular ratio was still of value in the determining of stresses.

The lecturer had said, "If the pillars are not able to sustain such a bending moment they in turn will be bent." He (the speaker) pointed out that they could not bend a structure without applying bending moment to it, so that the mere fact that "they in turn will be bent," implied that there would be a bending moment in the pillar. Then, the lecturer said "The stresses induced in the pillars will be sufficient to exceed the yield point, and the metal will stretch." How could they exceed the yield point without very high stresses, which was what they were trying to avoid? "But as soon as the pillars have been bent, and the beam takes its normal curve, there will be no longer the big bending moment put into the pillars." Those statements would really not bear thinking about. So soon as they started to try to prove that there was no bending in pillars they would invariably tie themselves into knots, and the lecturer, he claimed, had done so. Talking of calculations derived from people who worked out bending moments of pillars, the lecturer had said "Too frequently these seem to be that previous methods of designing pillars are all wrong." What they who were interested in calculating the moments in pillars tried to do was to differentiate between those pillars which would have heavy bending stresses and those which would have small bending stresses, and make a differentiation in those columns in actual practice. As a summary of his criticism, he claimed that the ordinary theory gave substantially accurate results, both for slabs and reinforced concrete beams, that no case had been put forward that the lecturer's new theory gave more accurate results, and, in point of fact, the author's results led to all sorts of fallacies and absurdities.

Mr. Charles F. Marsh said the author appeared to be obsessed with the ultimate effects, and deprecated the customary methods of basing calculations on working stresses. Much happened between conditions under which a member actually functioned and the condition under ultimate stresses. Ultimate conditions were in no way applicable to working conditions, and that was universally recognised in the design of all structures. For one reason, the concrete above the steel did not crack in properly designed members subjected to flexure under working load. The elongation of the steel when stressed at 16,000 per sq. in. was about 0·53/1,000ths, and with a high tensile steel stressed at 20,000 lb. per sq. in. it was about 0·66/1,000ths. Experiments had shown that concrete reinforced with steel would suffer greater strains before cracking. Below the steel the strain would naturally increase, and it would probably crack, at any rate, when high tensile steel was used and high stresses allowed. Another reason why ultimate conditions were not applicable to working conditions was that the stress-strain relations were entirely different. Generally, with respect to the modulus of elasticity, elasticity of materials was a fact which should not be neglected in design. The laws of elasticity must apply to reinforced concrete as to any other structural material since the fact remained that the strain in the concrete was greater than that in the steel under the same stress. He was firmly convinced that the value of 15 for the modular ratio was sufficiently accurate for all calculations, for reasons set out in a paper he had read on the L.C.C. Regulations. The author had very much criticised the customary methods of calculation, and stated that the reason for doing so was that the hypotheses used were not absolutely correct. Most of the points he had put forward were dealt with in a book published by the speaker eighteen years ago, which dealt directly with the same things which were brought forward by Mr. Dyson. When he (Mr. Marsh) dealt with the hypotheses, he made this statement: "It must, however, be borne in mind that all theories, even the most elaborate, are only approximate, being based on the best information that can be obtained on the subject. We are, consequently, justified in assuming hypotheses on which to base our calculations, which may not be absolutely correct." All engineering calculations were based on hypotheses, and all these hypotheses were to some extent untrue; the calculations for reinforced concrete were just as true as the calculations used for other structural designs. As to the cross-sections remaining plane surfaces during bending, he had said in his book: "We must treat this hypothesis with suspicion, as at best it is only an approximation to the real state of the case." That hypothesis was no more true for a steel joist than for a reinforced concrete beam, but it was sufficiently accurate for the purposes of working calculations. As to the factor of safety, that covered many doubtful matters other than the actual resistance and elasticity of a material, and if they did know everything about the materials, and could be assured of perfect workmanship, they might possibly be justified in doing away with the factor of safety altogether.

Mr. Ewart S. Andrews agreed with the main conclusions of Dr. Faber. High-tensile steel was not necessarily brittle It did not follow that, because the elastic limit of steel was not far from its ultimate strength, it was a material not suitable for structural work, and so far he agreed with the author. It was in piecing together the variations from accepted fact that he could not agree. As to the compressed area extending down as far as they liked, clearly it could not extend below the cracks, which they knew, from experiment, existed. With regard to Talbot's experiments, figures were given for the position of the neutral axis, and from a very rough calculation he had just made, it seemed to him that the calculation, working backwards from Talbot's results, did not differ seriously from the ordinary method of calculation. The real point raised by the paper was as to whether they were to base their calculations on working stresses or ultimate stresses.

Mr. Harrington Hudson said that most of the points which he wished to raise in connection with the paper had already been mentioned by Dr. Faber, so his contribution to the discussion would be very brief. In speaking of reinforced concrete subjected to simple compression, the author had referred to the gradual contraction of the concrete. He had stated, "such contraction of the concrete upsets any ideas we may have about the stresses in the concrete and steel being proportionate to the ratio of their moduli of elasticity," and then stated that, provided buckling of the rods could be prevented, the resistance of a reinforced concrete pillar was the sum of the resistances of the plain concrete pillar and of the steel. That seemed rather a sweeping statement. He agreed with the author that the present-day formulae for design of pillars might well be out-of-date in the light of recent investigations with regard to contraction, but he could not imagine that the design could simplify itself to the extent suggested in the paper. This contraction was divided into two parts, one, the shrinkage of concrete, and the other the plastic yield, and they should be considered separately. Shrinkage had been investigated in 1916 by A. C. Janni, who showed that in ordinary concrete used in reinforced concrete work, the shrinkage approximated to about ·05 per cent. in two or three months, and then remained fairly constant. Plastic flow was rather a doubtful factor. Shrinkage had quite a considerable effect upon the stress in a pillar. It was rather interesting to see how much stress had to be put into the steel before the strength of the concrete could be brought into play; he had worked out the value, and, taking 30,000,000 lb/in^2 as the elastic modulus of steel, and multiplying it by the shrinkage ·0005, gave the actual compressive stress in the steel when the initial tensile stress in the concrete was reduced to zero. That worked out to 15,000 lb. per sq. in. Then, working the concrete up to, say, 600 lb. per sq. in. would bring an additional 9,000 lb. per sq. in. on to the vertical reinforcement, and the final stresses in the pillar would be 600 lb. per sq. in. in the concrete and 24,000 lb. per sq. in. in the vertical reinforcement.

Mr. Edwin Palser thanked Mr. Dyson for his detailed paper, which would, he said, form the finest text-book for the juvenile student. Had the paper been read twenty-five years previously we should have made some headway and avoided much loss of capital. Speaking of the pioneers of reinforced concrete construction, he said thousands of buildings had been erected on a system designed by one of them and calculated on formulae different from the ordinary; as an example, he mentioned the Royal Liver Building in Liverpool, some of the columns of which had to support loads amounting to 1,500 tons. That building was erected twelve years ago, and the pillars were calculated by exactly the same method as that put forward by Mr. Dyson in the paper.

Mr. Gardner was disappointed that the discussion had not turned on the most important point raised by the author. The author had thrown down the ordinary theories, owing to the fact that cracks developed. He had said that the more the beam was stressed the lower the compression area would go until it reached the steel. Was that so? He would like the author to give the diagram of the truss action in a slab of 20-ft. span reinforced in tension only.

The President, referring to the collapse of the Knickerbocker Cinema at Washington, said that many things were becoming increasingly clear, and one was the danger of local stresses, the dangers of plasticity in places. If they were going to allow plasticity, they must bear in mind the consequences if the materials flowed.

Mr. Dyson, replying to the discussion, said the tests cited by Dr. Faber went to support the theory put forward in the paper. As to why he had picked out tests on those beams with big percentages of steel, it was because only in the big percentages did the wide divergence occur between his theory and the ordinary theory. He had taken experiments which showed the difference between the one theory and the other. He had criticised the ordinary theory, he hoped, destructively, and had put something else in its place. The only question was, did his theory sufficiently explain and co-ordinate the facts; if it did, it was a workable theory. He asked the members to study the paper in detail, and he hoped it would be the subject of discussion for some time to come. He was aware that he had a lot of prejudice to face, but he felt confident that his theory would be accepted soon.

A hearty vote of thanks was accorded Mr. Dyson at the conclusion of the discussion.

In a written contribution, **Mr. J. S. E. de Vesian** says he agrees with the lecturer that the computation of stresses subject to plastic deformation has not received sufficient attention, seeing that all concretes are neither perfectly elastic nor soft. It is not possible to make precise laws governing the deflection of concrete, the properties of which depend upon so many factors, such as the proportion and nature of the inert matters mixed with the cement, the quantity of water used, the intensity of ramming, the age of the concrete, the atmospheric conditions when the cement is setting, etc. Moreover, there are reasons to believe that the coefficient of elasticity of a given concrete may vary with the external stresses to which it is subjected. The uncertainty of the position of the neutral axis together with a relative plasticity of concrete are two causes of error in the calculation based upon a fixed modular ratio. As a matter of fact, the method advocated by the lecturer has many points of similarity with the semi-empirical methods applied with success by the pioneers of reinforced concrete. We must remember the numerous floor slabs (Monier) made so widely in Europe, and the Hennebique constructions built all over the world for the past twenty-eight years. The calculations of these structures were not based upon the principle of the modular ratio. The columns designed by Messrs. L. G. Mouchel & Partners, Ltd., were formerly calculated in practically the same manner as the lecturer's method. The New General Post Office is a good example. Even at the present day most Continental constructions on the Hennebique system are calculated with the same semi-empirical formulae proved and adopted by Mr. Hennebique twenty-eight years ago. He (the writer) had inspected a large number of these structures, and found them as free from defects in every way, and as sound as buildings calculated with (so-called) scientific methods. The lecturer, while refuting some "very elastic" if generally accepted principles, boldly proposes a method which, in his (the writer's) opinion, is based upon sounder principles. The theory enunciated certainly fits with observed results better than the modular ratio method seems to do. The elastic theory does not adequately explain why loading far in excess of the theoretical ultimate can be imposed upon sections without resulting in destruction. In fact, this very fact is in itself a demonstration of some inherent fallacy in the elastic theory. The following figures worked in accordance with the formulae devised by Mr. Hennebique before the adoption of the modular ratio, and still used on the Continent to a very large extent, form an interesting addition to and comparison with the figures given by the lecturer in his table, giving the steel required for slabs of varying thickness :—

Thickness of slab	8″	7½″	7″	6½″	6″	5½″
Percentage A_t	0·55	0·66	0·80	1·04	1·30	2·00

Mr. Dyson's written reply to the discussion contains the following : Dr. Faber appears to run entirely counter to the author's arguments, but his criticism shows that he was under some misapprehension. For instance, he (Dr. Faber) says : "If the lecturer could not find something in support of his theory except in structures where the percentages were 2·76, for example, about eight times as high as were used in practice, then he did not think the lecturer's theories needed very serious consideration for application to practical structures." The new theory gave identically the same result as the ordinary theory for the critical percentage, and practically similar values for smaller percentages, and it was only in the higher percentages that the divergence in the theories became very noticeable. Obviously, therefore, it was no use citing experiments on small percentages of steel in favour of one theory or the other. If any theory is to hold sway for some time it surely ought to embrace extremes. That is why the author picked out experiments on beams reinforced with large percentages of steel. Dr. Faber's statement that 2·76 per cent. is about eight times as high as used in practice is surprising. Most modern designers use between ·6 and 1 per cent., so that Dr. Faber ought to have halved his figure. But some of the pioneers like M. Hennebique, who were particularly practical, and had a great deal of experience, used very much higher percentages. The new theory accounts for what they found to be of practical advantage, that is to say, on the new theory high percentages in slabs are economical.

On the question of the straight line law, the author has indicated that if a straight line or triangular stress distribution be assumed with a higher stress in the concrete, very similar values will be obtained as by assuming an elliptical stress distribution with a lower and truer value for the ultimate stress developable in the concrete. It is also pointed out that the true crushing resistance ought to be determined on prisms or cylinders whose height is twice their width, and that the strength thus ascertained will be only about 80 per cent. of that given by cubes, which are the usual form of test piece. The diagram contrasting the theories therefore forms a fairly accurate comparison of what the author gets different from the ordinary theory, although he believes that it would be truer to adopt an elliptical stress distribution with lower working values than are usually adopted.

Dr. Faber says, "he hoped to show that Mr. Dyson's formulae were not within 100 per cent. in some places," but the maximum divergence (assuming the usually allowed stresses) is that the author would increase the calculated moment of resistance by just over 50 per cent. It is suggested, therefore, that Dr. Faber has exaggerated the difference. The author quite agrees that the quoted tests of Professor Talbot do not finally prove anything ; but Dr. Faber seems to waive airily on one side a difference of 32 per cent. as of no account. According to the new theory, with increasing large percentages of steel the difference between the computed moments of resistance likewise increases. This means that if the ultimate resistances realised show factors of safety in regard to the ordinary theory rising with increasing percentages, the new theory is in closer agreement with the facts. If reference be made to the results of Dr. Faber's experiments on singly reinforced beams, it will be seen that his tests support the new theory in this way.

The experiments of Dr. Faber were published in the issues of *Concrete and Con-*

structional Engineering for May and June, 1916. Unfortunately, they are no more conclusive than those of Professor Talbot ; because though the kinds of materials used are stated no tests are given as to the real strengths of the concrete and steel employed, and only one beam of each kind was tested. By either theory computations can be made to agree with the experimental results if we allow a possible range of stress. Between the lowest and highest factors of safety computed by Dr. Faber there is a difference of 35 per cent.

In commercial mild steel both the yield point and ultimate strength of large diameter bars are less than for smaller bars, because in the smaller sizes the metal cools in the rolling and the finishing is done at a lower temperature, thus putting cold work into the steel. The outside of such small bars is often harder and stronger than the core, as can be found by comparing turned-down test specimens against the rolled section. The size of the bars employed by Dr. Faber in his tests were as follows :—Beam 2, one ½ in. ; beam 3, two ½ in. ; beam 4, two ⅝ in. ; beam 5, two ¾ in. ; beam 6, two ⅞ in. ; beam 7, two 1 in. ; and beam 8, two 1⅛ in. His concrete was proportioned one part cement, two parts sand, and four parts ballast, graded between ¼ in. and ½ in. The age at testing was four months. It would be reasonable to take for such a concrete a true ultimate strength of 1,600 lb./in.², giving a working stress of 400 lb./in.² This would mean on the usual basis stresses of 2,000 and 500 lb./in.² respectively. The yield point of commercial mild steel is often round about 40,000 lb./in.² with an ultimate of 60,000 lb./in.². The tensile stress realised in reinforced concrete beams is somewhere about halfway between the yield point and the ultimate. Adopting a factor of safety of 4 and a working stress in the concrete of 400 lb./in.² throughout it is found by the author's new theory that Dr. Faber's tests would require a working stress of 11,000 lb./in.² in the beams with 1 in. and 1⅛ in. bars, 12,600 lb./in.² for the ⅞ in. bars, 13,000 lb./in.² for the ¾ in. bars and 13,800 lb./in.² in the third beam having ½ in. bars. The variation is 25 per cent. These results work very nicely. The second beam with the single ½-in. bar and the fourth beam with the ⅝-in bars are the exceptions ; on the new theory they would afford stresses of about 500 lb./in.² in the concrete and 16,000 lb./in.² in the steel. For isolated beams these results are quite reasonable. The author considers, therefore, that Dr. Faber's tests rather go to substantiate the new theory.

As regards Dr. Faber's other experiments on doubly reinforced beams, the only criticism the author desires to make is that no lateral anchors were employed to prevent the compression steel buckling sideways, and therefore the full strength could not be developed in the compression boom.

In the tests conducted at Manchester for the Concrete Institute's Sub-Committee on High-Tensile Steels, duplicate beams were made, and the results were very consistent. They were tested at the age of 10½ months. Being of good quality concrete they are free, at any rate, from Dr. Faber's criticism of Prof. Talbot's beams. Assuming an ultimate stress of 2,600 lb./in.² and elliptical stress distribution the author's new theory gives the stress realised in the steel in the following table :

CONCRETE INSTITUTE'S TESTS.

(Breadth of slabs 21 inches. Effective depth 6·06 to 6·19 inches.)

Mark.	Kind of Steel.	Percentage of Steel.	Resistance Moment.	Stress Calculated.
A	Mild	·70	272,200	54,600
B	do.	·71	278,700	53,600
C	do.	·58	235,200	54,000
D	do.	·58	229,400	54,200
G	Indented	·46	251,500	75,000
H	do.	·46	247,900	74,800
J	Spiral Bond	·46	249,500	74,200
K	do.	·46	260,600	78,000
L	Drawn Wire	·46	309,200	94,000
M	do.	·46	297,200	91,000

The tests on the steel used showed the following approximate values (in lb./in.^{2}) for yield point and ultimate strength respectively :—Mild steel : 46,000 y.p., 60,000 u. ; indented bars, 64,300 y.p., 95,500 u. ; spiral bond bars, 64,300 y.p., 81,400 u. ; bright drawn wire, 90,000 y.p., 95,000 u. The stresses realised in the steel in all cases were approximately halfway between the yield points and the ultimate strengths. The actual factor of safety realised by comparison with the working strength computed by the ordinary theory was 3·6 in the case of the mild steel reinforcement. Attention is directed to the beams reinforced with drawn wire where the same percentage was employed as for other special steels, the only difference being in tensile strength. The stronger material gave the greater moment of resistance just as in Professor Talbot's tests, for which the ordinary theory does not account.

Dr. Faber's remarks in this discussion might lead readers to believe that he did not agree with the author in having regard to ultimate resistance in practical design. However, in the issue of *Concrete and Constructional Engineering* for May, 1916, he says : " It is really the factor of safety on ultimate loads which is of most immediate practical value. An engineer is more concerned with what load his beam will carry than at what load the proportionality of load and deflection ceases. Indeed, even if there were no experimental difficulties in the elastic limit method, it is doubtful whether it is always what is wanted. Suppose, for example, beam ' A ' will carry 2 tons without exceeding the elastic limit of any of its constituent parts, and will not fail before 8 tons, and beam ' B ' will carry 2 tons within elastic limits, and will fail at 3 tons, most engineers would be willing to load ' A ' up to twice ' B.' "

Dr. Faber has misunderstood the remarks in the paper about bending moments in pillars in monolithic construction. The author was contrasting two tendencies that were in conflict.

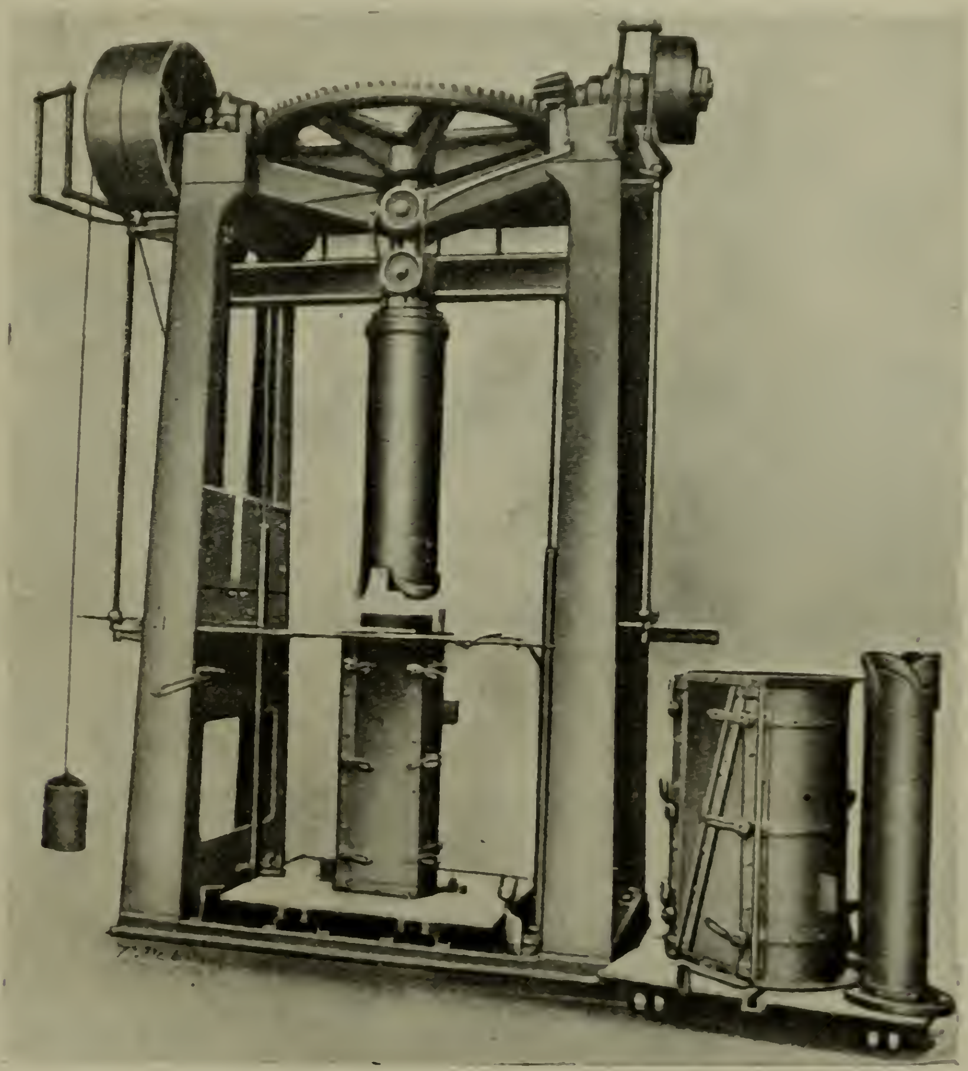
Dr. Faber makes the assertion that the paper sets out to prove that the usual method of designing slabs is all wrong. That was not the purpose of the paper, and seeing that the new theory gives similar results to the ordinary theory for moderate percentages of steel, and that most designers have not used large percentages, the paper agrees that the usual method of designing is right, though it contends that the theory is wrong.

In regard to Mr. Marsh's remarks, it seems most unscientific to base engineering calculations on hypotheses which are " to some extent untrue." Mr. Marsh remarks that it seemed to him that if the author's new methods of calculation were generally adopted some very dangerous structures would be erected. An entirely adequate answer is the contribution by Mr. De Vesian. The Hennebique formulae were made to fit results of experiments and experience ; they have been used for a very large amount of most successful work, and M. Hennebique's organisation used his formulae to design many more reinforced concrete structures than have been done by any other designer. The method of computing columns is the same as that of M. Hennebique and Mr. De Vesian shows that as regards rectangular beams the method which the author has tried to derive in a rational manner gives results in practical agreement with M. Hennebique's method of designing slabs. That is the greatest support that could be given as regards the practical utility of the new theory.

[At a meeting of the Council of the Concrete Institute on July 20, it was announced that as a result of a postal ballot of the members of Council, the Bronze Medal given annually for the best paper of the session had been awarded to Mr. H. Kempton Dyson for his paper on " What is the Use of the Modular Ratio ? "]

A NEW PRESS FOR CONCRETE PIPES.

THE rapid extension in the use of concrete drainpipes in this country, as well as in France, Belgium, and Germany, has created an interest in the development of machinery for their production. A machine recently produced by Camille Bochkoltz (Soc. Anon.), of Belgium, has features of special interest. The pressure is applied through a cylinder between the mould and the core. This cylinder, during its rotation, delivers definite quantities of concrete and compresses them in layers about 4 in. thick in such a manner that no joints can be detected between each layer. The shape of the cylinder is so arranged that the coarse particles are delivered to the interior



A NEW PRESS FOR CONCRETE PIPES.

of the web of the pipe, so that both its inside and exterior surfaces are smooth even when a coarse aggregate is used. The cylinder, after completing its work, returns automatically to its starting-point. Only one man is required to feed the machine, which works at the rate of one pipe, 4–12 in. in diameter, in three minutes, or a pipe 16–24 in. in diameter in ten minutes. Two more men are required to carry away the pipes, and one youth is needed to attend to the moulds. The power required is $\frac{1}{2}$–2 h.p. for small pipes, and 5–6 h.p. for the larger ones. Three moulds are needed so that one may be filled whilst the concrete in the second is setting and the pipes are being removed from the third.—*Revue de Matérieux.*

NEW QUAY AT SWANSEA.

THE new quay, or pier, illustrated herewith was constructed during the war for Messrs. Weaver & Co., Ltd., millers, of Swansea. The work was carried out under the general superintendence and in accordance with the scheme prepared by Mr. H. C. Portsmouth, F.S.Arc., of Swansea.

This pier was to replace an old timber pier occupying the same position which was found to be in too dangerous a condition to continue being used. It was necessary, therefore, in spite of great difficulties due to the war, to undertake the work without any delay and without in any way interfering with the loading and unloading of ships coming alongside, or with the use of the quay for foot traffic.

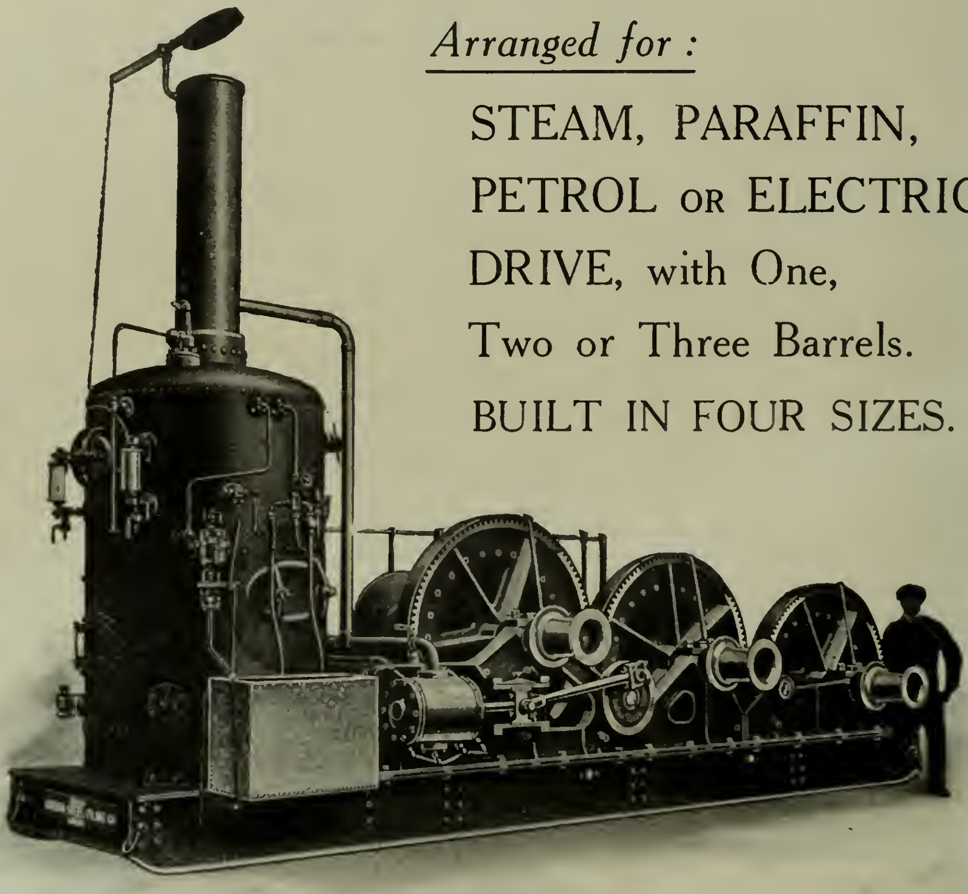
As this pier had to be constructed in the Beaufort Dock, where the water level varies only slightly, the whole of the braces had to be kept very high in order to avoid forming joints below water. To facilitate this operation the various horizontal and inclined members were made pre-cast with the bars exposed at each end to form a suitable joint with the reinforced concrete piles, the piles themselves being made to support the temporary scaffolding required to construct the beams and the deck. Fifty-two piles 14 in. by 14 in. were made, having a length of about 30 ft. These piles were driven through a considerable thickness of mud down into a bed of gravel. This operation was rather difficult, owing to the fact that a certain number of the old timber piles were found to be in the way, and had to be displaced, and also to the fact that the old pier was too weak to carry the piling frame required for driving the new concrete piles.

The total length of the quay is about 160 ft., and the width 27 ft. There is also a small portion supporting a bascule bridge constructed in steelwork and connected to the existing dock wall. The pier was arranged in bays of 15 ft. centres in a longitudinal direction, each bay being supported by four rows of piles. The deck was calculated for heavy rolling loads due to motor lorries and also to take the weight of the conveying plant and machinery for unloading grain from ships coming alongside.

The work was carried out up to a certain point by direct labour by Messrs. Weaver & Co., Ltd., under the occasional supervision of Messrs. Edmond Coignet, Ltd., of London, who prepared all the necessary working drawings. In order to hasten the construction, however, the completion of the deck and the bascule bridge were entrusted to Messrs. W. Alban Richards & Co., of London. The whole of the reinforcement is composed of round bars of mild steel arranged in accordance with the requirements of the Coignet system.

NEW QUAY AT SWANSEA.

The "Zenith" Friction Winch.



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MEMORANDA.

The British Empire Exhibition.

THE British Engineers' Association is organising the Shipbuilding, Marine, Mechanical, and General Engineering Section of the British Empire Exhibition to be held in London in 1924. The work of organising this Section and allotting space therein will be controlled by a Special Committee composed of the President and Council of the Association and a number of independent representatives of engineering industry. Within the limits of the space available—about 238,000 sq. ft.—every effort will be exerted to make the engineering exhibits representative of all that is best in modern British practice. Full particulars, plans, and forms of application for space will be available for issue at an early date. Inquiries should be addressed to Mr. D. A. Bremner, Director, The British Engineers' Association, 32, Victoria Street, London, S.W.1.

Concrete Mixer Adapted as Road Breaker.

A NOVEL attachment by which a concrete mixer was utilised for breaking up a road in Texas is described in a recent issue of *Engineering News-Record*. The breaking-up process was divided into two parts, first the cutting and then the actual breaking-up of the existing concrete. For the cutting operation, a framework was rigged up to carry an automatic drop-hammer which struck a chisel supported by springs at the bottom of the hammer leads. The hammer, which weighed 100 lb., was raised by a walking beam, and only two men, one to guide the chisel and one to operate the engine, were required. In order to break up the pavement after it had been cut, an automatic trip hammer was designed, consisting essentially of a 600-lb. hammer on a 14 ft. handle raised by a cable running over a sheave in a steel frame about 16 ft. high. This rig was also mounted on a concrete mixer. The trip apparatus was attached to the hammer by hand, but the tripping was automatic. The base of the hammer handle contained a large horizontal screw, one end of which was attached to the frame of the mixer. On the other end was a handle, by turning which the side swing of the hammer was controlled. Five men operated this machine.

Protecting Concrete in Winter.

THE importance which in America is attached to the carrying out of concrete work throughout the year, and the success which has attended the efforts to make concreting possible during the coldest weather, are shown by an account in an American contemporary of the construction of a large pier at Philadelphia. The pier is a two-story structure, 550 ft. by 75 ft., consisting of skeleton-steel frame of approximately 1,000 tons, concrete floor slabs, and brick walls with limestone trimmings. The usual winter protection of heated aggregates for concrete, anti-freeze compound for brick and mortar, and night protection by tarpaulins were found inadequate to meet the weather conditions, and protection was afforded by 20-oz. waterproof tarpaulins stretched over a frame made of 3 in. by 6 in. lumber. The entire structure was thus enclosed, the canvas being turned over at the top and fastened to the roof already in place. The enclosure left a space of about 4 ft. between the canvas and the outside columns, and in this space radiators, on the ground level, furnished ample heat for placing the brickwork properly. After the walls were up the canvas protection, with radiators between the canvas and the brick walls, formed an envelope of warm air around the entire building, giving absolute protection to all interior work. The heating plant consisted of four sections each having about 1,250 sq. ft. of radiation, directly connected to an 80 h.p. vertical boiler operating at 5 lb. pressure, centrally located. Each of the sections was valved so that any combination could be used to offset daily wind and weather conditions. The plant consumed between one and two tons of coal per day and gave entire satisfaction.

Dover Pier Viaduct.

MESSRS. DAVID BALFOUR & SON, of 3, St. Nicholas Buildings, Newcastle-on-Tyne, were appointed by the Dover Corporation to act as independent engineers to carry out tests on the reinforced concrete work in connection with the Dover Viaduct and Bridges described in our issue of June last, and the tests detailed in that article were carried out by them.

MOTOR-RACING TRACKS.

THE motor road in Grunewald, near Berlin, specially built for racing and opened officially last September, consists of two parallel roadways, each about 12½ miles long and 27 ft. wide, about 800 ft. of which is of concrete. This portion is in two parts: one portion, 9 in. thick, is made of 1 : 2 : 4 concrete, and the other, 7 in. thick, of 1 : 2 : 5 concrete surmounted by a 2-in. layer of 1 : 2 : 2 concrete. Joints, 0·16 in. wide, filled with asphalt are made every 4 inches. After the first racing season, the macadamised portion of the road showed numerous inequalities and pits, but the concrete portion showed neither irregularities nor cracks.

PROSPECTIVE NEW CONCRETE WORK.

ASHBORNE.—*Gasworks.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £12,000 in connection with the gasworks.

BANGOR.—*Waterworks.*—The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £13,256 for water supply purposes.

DONCASTER.—*Open-Air Bath.*—The Baths Committee has recommended the Corporation to apply for sanction to borrow £5,000 for the construction of an open-air swimming bath at Hexthorpe Flatts.

GRANGE.—*Bathing Pool.*—The clerk to the U.D.C. has been instructed to apply to the Ministry of Health for sanction to a loan for providing a bathing pool.

HARTLEPOOL.—*Bathing Pool.*—The T.C. has approved a scheme for an open-air bathing-pool, 250 ft. long, and from 2½ ft. to 6 ft. deep, at the South Cliff.

ILKLEY.—*Sewage.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £7,000 in connection with the extensions and improvements of its sewage disposal works.

MACCLESFIELD.—*Reservoir.*—The Macclesfield Corporation is considering the construction of a new reservoir at Trentabank at an estimated cost of £91,600.

NEWPORT.—*Open-air Baths.*—The Newport (Mon.) Corporation Parks Committee proposes to provide open-air swimming baths in Shaftesbury and Crindan Parks.

PORTSMOUTH.—*New Road.*—The Corporation is considering a proposal for the construction of a new roadway into the town from the north. The estimated cost is £213,065.

REDCAR.—*Swimming Pool.*—The U.D.C. has under consideration the construction of a swimming pool.

REGENTS PARK.—*London.*—The executive of the London Zoological Gardens has decided to construct an aquarium of about 400 ft. long at an estimated cost of £50,000.

ROTHERHAM.—*Reservoir.*—The Rotherham Corporation has decided that the borough engineer be authorised to prepare a scheme for the construction of a new service reservoir at an estimated cost of £50,000.

SOUTHEND.—*Road Works.*—The Corporation has decided to apply to the Ministry of Health for sanction to borrow £30,000 for the construction of a new road from Cuckoo Corner to Sutton Road, and for widening and extending Brook road.

WELSHPOOL.—*Waterworks.*—The T.C. has decided to apply to the Ministry of Health for sanction to borrow £13,174 for water supply works.

WESTCLIFF.—*Pier.*—The Southend Corporation is in favour of a scheme for constructing a short pleasure pier on the foreshore.

WEST HARTLEPOOL.—*Road.*—The West Hartlepool T.C. has approved a scheme for the construction of a new road from the south end of the town to join Seaton Lane at a cost of £30,688.

TENDERS ACCEPTED.

CLEETHORPES.—*Bathing Pool.*—The Cleethorpes U.D.C. has accepted the tender of Messrs. D. G. Somerville & Co., Ltd., of Victoria Street, London, at £12,985 2*s.* 10*d.*, for the construction of a reinforced concrete bathing pool.

HOUNSLOW.—*Bridge.*—The Heston and Isleworth U.D.C. has recommended for acceptance the tender of Messrs. J. Garrett & Son, Balham Hill, S.W., at £325, for the construction of a ferro-concrete footbridge over the river Crane.

MIDDLESEX. — *Bridges.* — The Middlesex C.C. has accepted the tender of Messrs. Allen Fairhead & Son, at £5,898, for the construction of four bridges across the Pymmes Brook on the trussed concrete steel system.

MORPETH.—*Concrete Wall.*—The Morpeth Corporation has accepted the tender of Mr. R. C. Hall, of Morpeth, at £2,731 7*s.* for the erection of a concrete retaining wall at Bay's Land, and making up of the roadway in tar macadam.

NEW COMPANIES REGISTERED.

NEW ADAMENT PLASTER CO., LTD. (181,570). Registered May 5. 10, Norfolk Street, Manchester. Dealers in plaster of Paris, cement, etc. Nominal capital, £2,000 in 2,000 shares of £1 each. Director: G. E. Fussell, Haulfre Coed, Pella Road, Colwyn Bay. Qualification of directors, one share; remuneration to be voted by Company.

VAUX PATENT CONSTRUCTION CO., LTD. (181,008). Registered May 19. 2, Gresham Building, Basinghall Street, E.C.2. Manufacturers of tiles and blocks for use in concrete construction. Nominal capital, £5,000 in 5,000 shares of £1 each. Director: Noble Vaux, 4, Earl's Terrace, W.8. Qualification of directors, one share; remuneration of directors, £200 each.

RECENT PATENT APPLICATIONS.

156,551.—E. Maier: Reinforced building elements.
157,883.—L. Faure-Dujarric: Reinforced concrete structures.
167,138.—K. Winkler: Process for rendering waterproof mortar, cement and concrete.
170,260.—K. Winkler: Process for treating mortar, cement and concrete.
172,021.—E. Lechat: Moisture-tight building blocks.
175,179.—G. H. Stonehouse: Concrete brick-making mould.
175,219.—G. Norman: Concrete building construction.
178,473.—E. C. R. Marks (Aktiebolaget Lean): Hollow building blocks.
178,514.—B. E. Bowen: Concrete walls.
178,547.—A. F. Woodman: Concrete walling.
178,691.—W. H. Kerr: Moulds for making concrete slabs.
179,222.—B. Bradley: Concrete pipes.
179,350.—G. A. Tawse: Reinforcement for concrete construction.
179,399.—J. H. Harrison: Machines for moulding concrete blocks.
179,624.—J. Dooley: Expanded metal for reinforced concrete.
179,703.—E. B. Hillman; H. Kimber, and H. Dadisman: Reinforced concrete walls.
179,811.—G. H. Howse: Method of treating or preserving steel or iron work against corrosion.
179,975.—H. Wilkins: Concrete blocks.
180,149.—D. L. Neil: Apparatus for manufacture of concrete blocks.
180,169.—W. Wilkie: Concrete blocks.
180,181.—E. Doherty: Concrete blocks.
180,204.—S. Tetsuka and F. Naito: Concrete sheet piles.
180,222.—O. C. Richardson and E. Meredith: Building blocks.
180,388.—F. H. Rogers (Acme Cement Plaster Co.): Forms for building blocks.
180,430.—E. F. Needham: Wall construction.
180,505.—H. Banger: Machines for moulding concrete blocks.

TRADE NOTICES.

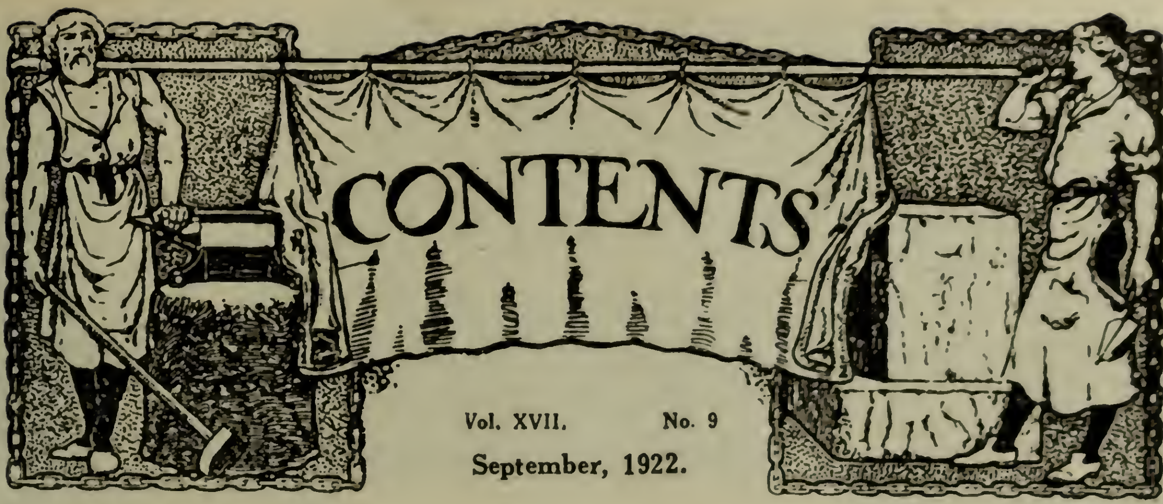
The Australian Concrete Machinery and Engineering Co., Ltd., manufacturers of the well-known "Australia" block-making machine, and the "Tonkin" mixer, have removed from Salisbury House, E.C.2, and Lavie Mews, North Kensington, to larger premises at Pordon Road, Brixton, S.W.9.

Concrete Roads at Queen's Island, Belfast.—A new concrete road is now being constructed by Messrs. Harland & Wolff, Ltd., at their works at Queen's Island, Belfast, and is being reinforced by Walker-Weston pyramidal double-layer reinforcement, which has been used by Messrs. Harland & Wolff for a number of roads laid in their shipyards during 1920. These are stated to have stood the test of wear by heavy traffic with success. New concrete roads are to be constructed at the London works of Messrs. Harland & Wolff on the Walker-Weston principle in the course of this year.

Concrete Roads at Tilbury.—Interesting examples of reinforced concrete roadways are at present being constructed at Tilbury, under the direction of Mr. S. A. Hill Willis, Surveyor to the Tilbury Urban District Council. About five to six miles of reinforced concrete roads are to be constructed, a fair proportion of which are now well on the way. The reinforcement being used is "B.R.C. Fabric Reference No. 9," made by the British Reinforced Concrete Engineering Co., Ltd., of Manchester.

Reinforced Concrete Bridge at Saskatoon.

(See page 584.)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Vol. XVII. No. 9
September, 1922.

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 9. LONDON, SEPTEMBER, 1922.

EDITORIAL NOTES.

OLD BUILDINGS AND NEW MATERIALS.

THE recent Press discussion on Tintern Abbey has once more brought forward the question of our ancient monuments, their present condition and their future. The value of these links with the past to students of architecture and to the general public who take a pride in the history of their country cannot be doubted, and, in fact, was not raised in the correspondence referred to, which was confined to the methods of keeping these buildings intact. There appear to be two sharply-divided schools of thought on the subject, who draw a fine distinction between the words "protection" and "preservation"; the advocates of the former method desire to see the old buildings left untouched but propped and shored up where necessary to prevent them from tumbling down, while those in favour of "preservation" would like the ancient structures to be held in their original position by the addition of buttresses or other constructional expedients, which in time would become toned down with age and, so far as outward appearance goes, practically indistinguishable from the original structure. We are heartily in sympathy with any endeavour to make these heritages from the past secure for the benefit of future generations, but at the same time objection can be taken to both methods; for while shoring is likely to be an eyesore the addition of modern work, however cleverly it be made to resemble the old, and however much the action of time and weather help it to harmonise with its surroundings, can never be anything but a sham. But the condition of Tintern Abbey was apparently such that shoring was out of the question, and H.M. Office of Works (which has taken charge of the ruins) decided to strengthen the ancient walls with buttresses. This, however, was abandoned in favour of strengthening the remains by inserting reinforced concrete into the walls themselves, and it is this use of a modern material to preserve an ancient one which gave rise to the discussion.

The new work at Tintern Abbey comprises chiefly the insertion of reinforced concrete beams in trenches cut in the tops of the walls in order to supply the tensile strength lacking in the walls themselves. Apart altogether from the nature of the material used, there is, we think, much to be said in favour of the principle of preserving ancient buildings by a process which is invisible to the eye, and leaves the structure with exactly the same outward appearance it possessed before any work on it is done. The point was raised that when buildings which have been repaired in this manner finally fall down, or if in years to come the new material is exposed, future generations will be deceived into thinking that reinforced concrete was known to mediæval builders and was originally incorporated in the building. In face of the records now kept of all these works such an event is hardly possible, but even in the unlikely event of it happening we fail to see that it is a worse deception than twentieth-century buttresses and other new work erected with the special intention that it will rapidly take on the same appearance as the original structure. Of the two evils it certainly seems the lesser is that in which the building is in no way altered to the onlooker.

In the correspondence a great deal of misapprehension as to the expansion and contraction of concrete, and the possibility of the reinforcement rusting, is apparent. It should be known that concrete properly graded, properly mixed, and used under trained supervision is absolutely impervious to moisture, and that therefore it is quite impossible for steel embedded in good concrete to rust—and it is to be presumed that nothing but the best concrete and skilled workers are used on the preservation of ancient monuments. So far as any likelihood of the expansion and contraction of the steel cracking the concrete is concerned, the fact is that in their susceptibility to heat and cold both materials are practically equal, and expand and contract together without any cracking of the concrete; moreover, the extent of the expansion and contraction of reinforced concrete is almost identical with stone, and therefore has no tendency to disrupt the surrounding masonry. It is much to be regretted that the daily Press is made use of to air views based on insufficient knowledge, and to inculcate wrong ideas into the minds of the public.

ROADS AND ROAD USERS.

To the relief of all who have occasion to use our highways the road-mending season is now drawing to an end for this year, and the roads will assume their normal state until the annual upheaval takes place again next spring. The yearly expense enforced on the public by time wasted, appointments missed, the delay in the delivery of goods, by being held up at busy crossings where the road is "up," or by the wear and tear on vehicles in making detours to avoid points of congestion, must amount to a very considerable sum, and might very well form the subject of inquiry by "Anti-waste" enthusiasts. "London," Lord Rosebery has said, "is the pride and the problem of our race," and the traffic problem in London or any other large town is one which not only grows more serious with the increasing volume of traffic but becomes more difficult of solution with the upward tendency of land values and the practical cessation of the garden city movement since it was checked by the increase in the cost of building. The inconvenience and delay caused by road repairing in urban areas, linked up as it is with other civic questions, will probably not be eased until the money is available for carrying out town-planning schemes on a large scale, but there is, we think, one aspect of the problem in rural areas which might be much alleviated. We refer to the tar-spraying of roads, which when it is in full swing makes motoring the reverse of pleasurable. Not only is it necessary to lose valuable time when travelling over newly-tarred stretches of road, but even at the slowest speed spots of tar and tar-coated pieces of grit are thrown up by the wheels, and from one passing car to another, to ruin expensive coachwork. The tar sprayed on country roads is also claimed by eminent authorities to be responsible for killing large numbers of fish in streams in the vicinity of roads which have been so treated, and in certain areas to have polluted the water supply. For macadam, of which material the bulk of the main roads are constructed, some kind of dust-preventing top dressing is essential in these days of fast traffic, but anyone who has been put to considerable expense in having the body of his car repainted might very well be excused for thinking the remedy worse than the disease. The only real remedy is a road with a dustless surface, on which no surfacing is necessary, and everyone who travels by road to any extent will be glad to see the many new reinforced concrete roads now being built and left with a bare surface. To be compelled to reduce speed to crawling pace on a newly-tarred road after travelling at high speed on a concrete road is an experience which should convert any motorist to the latter type—the remarks of a chauffeur which we recently heard on a similar occasion in the county of Middlesex will not bear printing! That the advantages of the concrete road are realised in the United States, where motor-cars are almost as numerous as bicycles

[*Mr. W. H. Weeks, Architect.*

School at Watsonville, California: Detail of Doorway.

[This illustration shows how well concrete lends itself to exterior decoration, which can be carried out in moulded concrete at a fraction of the cost of carved stone. Several concrete school buildings in America were illustrated in our last issue.]

in this country, is shown by the latest figures to hand, which show that there are now 22,495 miles of concrete roads in that country, compared with 6 miles twelve years ago.

ORNAMENT IN CONCRETE.

With all building materials, and especially with concrete, it would make all the difference to the chances of obtaining really suitable ornament if it were understood that it is the building itself which properly suggests the kind of ornament required, and that it is part of its growth. Friezes, mouldings, bas-reliefs, cornices, applied ornament of any kind, which are not the outcome of the building, will always have an artificial and " stuck on " appearance. As Michael Angelo felt the ideal figure which he had to release to be hidden in the block of stone, so there lies concealed in the architectural construction the ornament which, when discovered, will give to it the greatest dignity and significance. We are not likely to reach either when from mere use and wont we introduce ornament without any such necessity. The introduction of ornament is often merely a bad habit, and a survival from other periods. Not applied under the same structural conditions it can have no such value as the example from which it is borrowed, and will look only what it is—an imitation without either the inspiration or necessity out of which grew the original.

Architectural enrichment should be employed only where it is possible to include it properly, and should never be introduced merely from habit. There has been much abuse in this way over the last sixty years or so, and the object of introducing so much ornament has not always been a genuine one. No value is created in the minds of those who appreciate the intrinsic nature of beautiful ornament in introducing a substitute for it, in order to give the appearance of value, when the enrichment is without any real inspiration or craftsmanship, as we may see in the carved embellishments of some suburban villas. All this is the appearance of value rather than the reality.

In a material such as concrete it would be well to rely, as the fundamental, on the structural proportions. If ornament is to be introduced it should include the character which the working of the material in the hands of craftsmen of imagination and experience can bestow. The situation of a building and its proportions will determine the scale, the depth of relief for light and shade, and other requirements, which will differ in the measure of the difference between the buildings themselves. How, then, should ornament intended and planned for one situation be suitable for another ? It is probable that the best results will not be obtained by " period " treatment—unless it be our own period. There are plenty of craftsmen who, if put on to it, are able to give imaginative treatment to the working of ornament in concrete, and there is great scope for their work. It should be the aim of the industry to encourage artistic sensibility to the study of these problems, so that the material may clothe itself with an ornament at once vital to itself and original and beautiful in character. When this further development is well in hand we shall have taken an important step towards promoting the architectural possibilities of concrete.

SOME RECENT CONCRETE BUILDINGS IN GERMANY.

By H. J. BIRNSTINGL, A.R.I.B.A.

HANS JESSEN is an architect whose work is typical of a certain aspect of contemporary German work, and in common with most modern designers he makes full use of concrete. A school, which has recently been erected to his design outside Berlin, is illustrated herewith. Its severity of outline and simplicity of treatment are logical and satisfactory. The huge gable and the thin verges seem to be reminiscent of certain German toys. This connection is often discernible, particularly in South Germany, and it would be interesting to speculate to what extent the toy designers are influenced by architecture, and the architects by the toys with which they became acquainted in their childhood.

A feature about much German work is its sense of completeness, finish, and congruity, and this is to be to some extent accounted for by the fact that there is a complete architectural service to which mural decorators, sculptors, and craftsmen of all kinds contribute under the directing force of the architect. Architecture is not divorced from, but is part of, the contemporary art movement, and so the decoration and equipment of a building is never an extraneous application but an integral part of the original conception. In the school illustrated the internal finish is simple, mouldings are almost eliminated, for the sake of cleanliness, and the wall surfaces are tinted in plain colours. On the ceiling of the main staircase landings there is an odd herring-bone pattern in blue and yellow, giving a curious but by no means unpleasant effect of sky and sunlight. The idea of concentrating the only bright colour on the ceiling is a novel one, and in this case quite satisfactory.

Since the war Jessen has been respon-

[*Hans Jessen, Architect.*

SCHOOL NEAR BERLIN.

sible for much housing work. Concrete and brickwork are the usual materials, with here and there an all-timber house. A row of houses in blocks of four which appear to have a better finish than many of our own Government housing schemes is here illustrated. Materials and workmanship are good, and the presence of such features as the louvred shutters and the trellis work around the doors shows that attention has been given to detail and appearance. The ground-floor windows appear somewhat small, and their position is not quite satisfactory. The reason for this is that all the houses are cellared, and in order to minimise excavation the ground floor is raised some 3 ft. above ground level. The entrance leads on to a small landing with flights of stairs up and down to the first floor and to the cellar. The accommodation comprises a living-room, wash-house, and kitchen on the ground floor, and a bath-room and three bedrooms above. The walls are constructed in solid monolithic concrete, and the ground floor is also concrete reinforced with rolled steel joists. Even in the brick houses the walling below ground is generally of concrete, likewise the ground floor. In these particular houses the flues are of brickwork, but concrete is often used for this purpose.

The different building methods which one notices, particularly in South Germany, are interesting. In work of this kind there is an almost total absence of ladders ; ramps are run up to a wide platform carried on trestles, on to which materials are wheeled. In place of lathing, rolls of bamboo canes strung together on wires are attached to the underside of the joists. In districts where extremes of climate prevail double casements are fitted at considerable additional expense. In almost every case the houses are fitted with electric light. The wiring is by means of cable fixed in the houses to porcelain cleats, and not cased in. Some of the designs are by no means so pleasing as those which accompany this article. For instance, an attempt is made to imitate timber forms in concrete, which is far from pleasant, or a desire for novelty at any price leads to the abandonment of all restraint. In large blocks of dwellings curious effects are sometimes obtained by concentrating the windows in groups and leaving large expanses of unbroken wall surfaces, and, where concrete is employed, the design embodies various curves for openings, projections, roofs, dormers, and gables, which are unlike anything that we are accustomed to see in other materials. This is interesting

[*Hans Jessen, Architect.*

School near Berlin : Interior.

[Hans Jessen, Architect.

POST-WAR HOUSES NEAR BERLIN.

since it shows an appreciation of the possibilities of the material, for an arch can be turned in concrete of a shape which if built up of discrete brick or stone voussoirs would be costly and ugly. The fact that these forms strike us as unusual is no reason to condemn them when we consider how well they express the medium in which they are built.

A comparison between American and German methods of designing in concrete would be an interesting study. Of the two it would probably be found that the Germans are more daring in their treatment, but there is certainly much that we can learn with advantage from both, although, with our fine tradition of domestic work, which neither of the other countries possesses, it behoves us not to be too iconoclastic.

Reinforced Concrete Reservoir at Yeovil.

A REINFORCED concrete reservoir, of 800,000 gallons capacity, has just been completed at Hendford Hill, Yeovil, for the Yeovil Town Council. The new reservoir is divided into two compartments by a submerged wall 6 ft. 6 ins. high, so that there will always be at least 200,000 gallons of water available in one half when the other is being cleaned out. The reservoir is " dish " shaped, having the lower half of the sides sloping and the upper half vertical. It is rectangular in plan, the internal dimensions being 114 ft. 10 in. by 59 ft. 10 in. at the top. The depth of water when the reservoir is full is 12 ft. 6 in. There are forty columns 10 in. square at 14 ft. centres, and fifty main beams are 12 in. by 10 in., 114 secondary beams 10 in. by 5 in. and the roof slab $4\frac{1}{2}$ in. to $5\frac{1}{2}$ in. deep (1 in. cross-fall having been given to allow the water to drain off). The side walls and division walls are 6 in. thick, and are not rendered. The side walls are buttressed at 7 ft. centres by 90 buttresses 7 in. by 12 in. The horizontal and sloping floors are 12 in. thick, with cement rendering $\frac{3}{4}$ in. thick. The reinforcement in the walls, buttresses, floors, beams, and columns consists of steel rods varying from $\frac{1}{2}$ in. to $1\frac{1}{8}$ in. diameter, and the roof is reinforced with lattice. One side wall is double reinforced to allow for future extension.

NEW WORKSHOPS FOR THE GAS LIGHT & COKE CO. (See p. 571.)

NEW WORKSHOPS FOR THE GAS LIGHT AND COKE COMPANY.

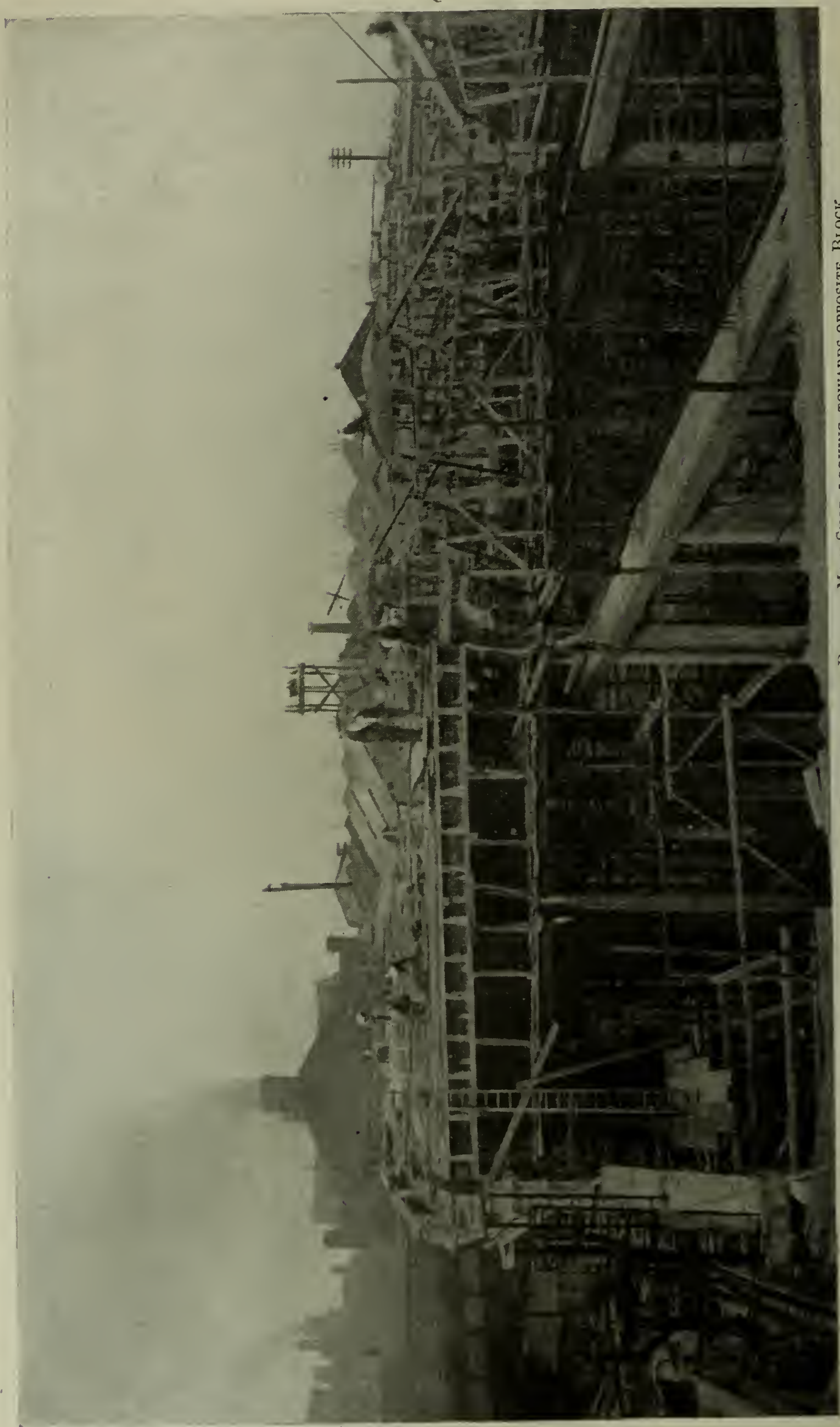
AMONGST the industries which during the past few years have made an extensive and steadily increasing use of reinforced concrete the gas companies and industries affiliated thereto take a prominent place, and the Gas Light & Coke Company is amongst the foremost.

Within the Company's works at Beckton and Bromley the applications of reinforced concrete are numerous, and all kinds of structures come within its scope. This article, however, is confined to the new workshops at Beckton. This shop, which has only just been completed, is the practical outcome of a scheme involving the centralisation of all the mechanical work attached to the upkeep and repair of the engineering plant throughout the works. With this in mind, the whole building has been carefully planned and the many repair shops, workshops, electricians' shops, etc., which hitherto have been too scattered for efficient supervision, are now all embodied in the new building.

The plan and longitudinal section of the building given on p. 576 shows that the main part consists of the workshop, at the one end joined up to an office building and at the other end to a stores department, which also provides accommodation for the workmen by providing space for their messroom and lavatories.

The shop is on the most modern lines of "daylight factory" construction, the walls consisting of a structural reinforced concrete framing filled in with windows reaching from the dadoes 4 ft. above ground to the roof, which is flat with a double skylight, through the entire length of the building. The main dimensions of this shop are 309 ft. by 125 ft. by 35 ft. high, and it is divided up by three rows of columns into four aisles. At a height of 26 ft. above the floor the columns are connected up with crane girders, providing runways for four overhead travelling cranes which in this way can cover the entire area of the shop.

NEW WORKSHOPS FOR THE GAS LIGHT & COKE CO.: INTERIOR, LOOKING FROM GALLERY.



New Workshops for the Gas Light & Coke Co.: Shuttering for Roof of Main Shop, looking towards opposite Block.

The office end, which covers an area of 125 ft. by 20 ft., has two floors above the ground floor. The first floor is occupied by the foremen's offices with dining-rooms, etc., while on the top floor the mechanical engineer and his staff are accommodated, and also the drawing office. On the ground floor railway tracks are brought into the shop through three large gates. These 10-ft.-high openings just allow the works engines to pass; the shop is also to serve as a repair shop for these, and therefore one of the openings has been carried through the first floor and is fitted with a double gate to allow one of the works travelling cranes to be eventually taken into the shop.

On the ground floor, also, are situated the workmen's entrances (five in number). To enter the shop the men have to pass through narrow alleys past the timekeeper's offices, and here the checking off at the beginning and end of a working day is done, and an easy control over the men is effected as they must pass through this end of the building to and from the shop.

On the upper floors there are two galleries open towards the shop, from which an excellent view over the whole area is obtained, thereby giving good opportunities for supervision from the top floor as well as from the first floor. From the latter a staircase leads down into the shop. The main stairs are not connected directly with the shop except through a door to the first-floor gallery. This, however, would be kept locked to prevent workmen passing out of the building unnoticed.

The stores end covers an area of 57 ft. by 125 ft., and has two floors above the ground floor, as at the office end. One opening for a railway track divides the ground floor into two sections, namely, an electricians' shop and a store-room, the latter being connected with the stores covering the larger part of the first floor. The stores portion, in the first instance, was meant to be self-contained, having no access whatever to the shop itself except sliding doors to the open at the back of the building and sliding windows towards the shop through which the tools can be handed. Later on, however, it was decided to take two narrow-gauge tracks from the shop into the ground floor stores, and sliding doors were fitted here also. On the first floor the space

New Workshops for the Gas Light & Coke Co.: Concrete Chuting Plant.

not occupied by the stores is used for lavatories, which are parted from the shop by a 5-ft.-high reinforced concrete wall with windows above. In order to comply with the sanitary regulations for ventilation, two air shafts have been carried through the next floor to a point well above the roof.

The second floor is one large room to be used as the men's messroom, and besides having windows on the three sides to the open and on the fourth side towards the shop this room gets a splendid light from a skylight in the centre, where arched reinforced concrete trusses and a ridge beam form the carrying structure for the glazing bars and glazing.

The whole building is carried on rein-

New Workshops for the Gas Light & Coke Co.: Hoisting Pre-cast Concrete Purlins into Position.

NEW WORKSHOPS FOR THE GAS LIGHT & COKE CO.: HOISTING PRE-CAST CONCRETE PURLINS INTO POSITION.

forced concrete pile foundations, the subsoil being as usually found in this part of the Thames valley. In this case three distinct layers were met with, first, about 8 ft. of made-up ground, then marsh for about 12 or 20 ft., until the London clay was reached at a depth of from 20 to 30 ft. As the surface of this seemed to be sloping towards the river, three test piles were driven and a length for the piles from 25 to 28 ft. was decided upon. When driving commenced, however, still longer piles were found to be necessary at the south-east corner of the building, and at this point all piles had to be lengthened 8 to 10 ft. after having been driven. Here trouble arose from the fact that the high-water level was only 4 to 5 ft. below the ground level; this was overcome by pumping, and in the worst cases the two piles forming the foundations for each column were joined up by a heavy block of reinforced concrete carried well below the top of the piles. For the foundations further trouble arose when the lines of the piles interfered with some old limekiln foundations. These were, however, found to go right down to the solid ground, and by bridging over from one foundation pier to another with heavy reinforced concrete beams a sound foundation for this part was obtained.

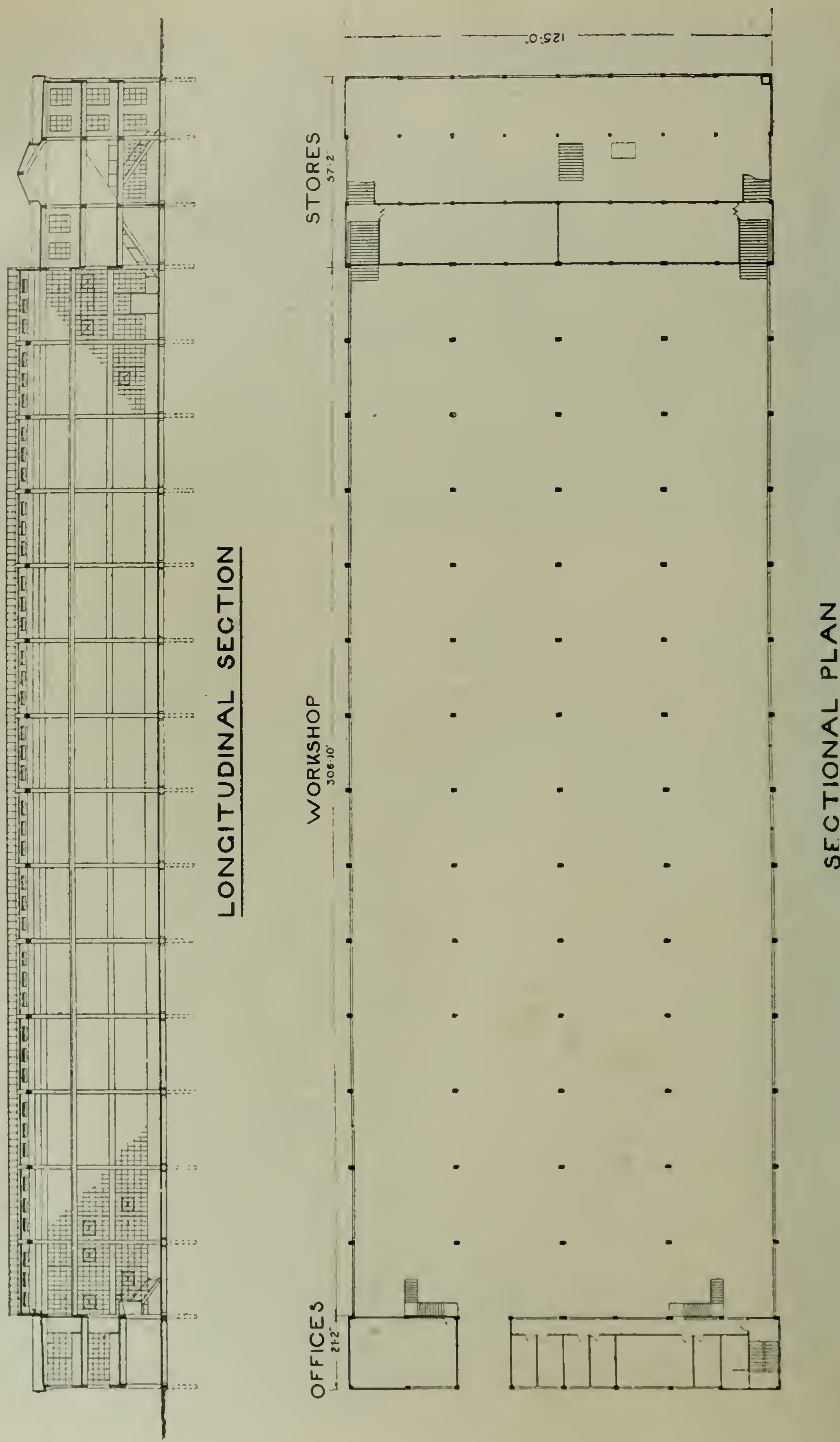
The superstructure presents many interesting features. It is of reinforced concrete throughout, even to the glazing bars for the skylights.

Asbestos cement is used for the ridge capping, and zinc plate for the louvre blades which form part of the skylights. The carrying structure for these consists of longitudinal purlins supported by the arched roof trusses. The purlins, which were pre-cast on the ground and hoisted into position afterwards, have openings for the louvres and are designed as "Vierendeel" girders. The flat roof sections on each side of the roof-lights are specially designed to act as supports for the roof trusses by taking the horizontal thrust, hence the ties across in two places only. The flat roof will also serve the purpose of distributing the wind pressure over the whole length of the building, ultimately carrying it to the ends, which are designed as stiff frames capable of enduring the stresses introduced therefrom.

The crane-girders are designed for travelling loads of ten to twenty tons for the external and internal girders respectively, and the section adopted is calculated to resist the considerable twisting moments introduced when the cranes in two adjacent bays do not coincide.

The nature and lay-out of the plant was as follows:—

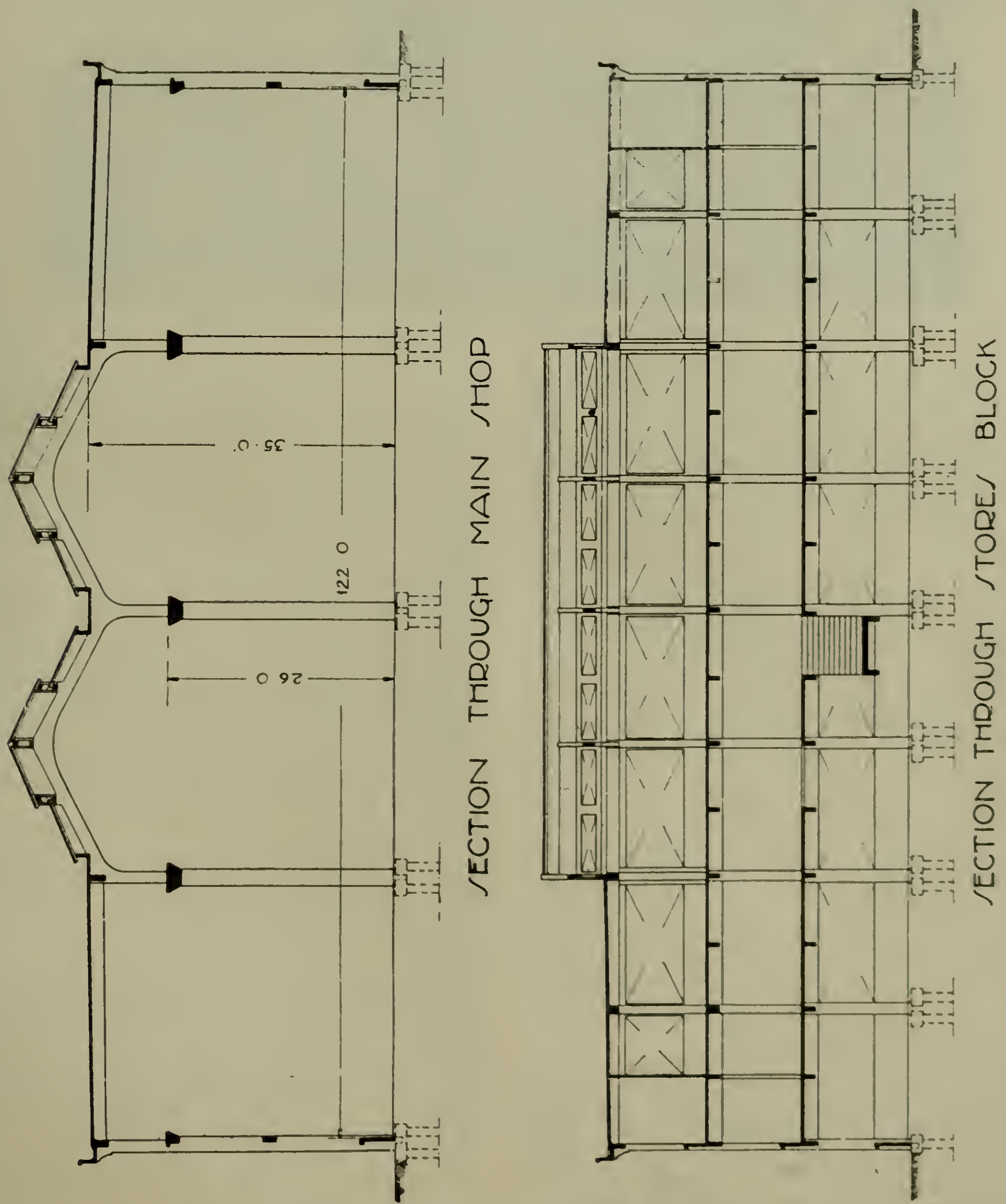
Two electrically-driven mixers were installed inside the shop. A railway track which already existed and was



New Workshops for the Gas Light & Coke Co.

connected up to the Company's sidings went right through the shop; alongside this were the cement in sheds close to the mixers, and sand and gravel between in temporary wooden bins. From these the materials were brought forward on a jubilee track laid on the other side of the materials. For each mixer there was an elevator. At the office end this was an ordinary wooden tower with a lifting stage taking the full skips up and the empty ones down, the concrete being wheeled on scaffolding to the place of concreting in two-wheeled handcarts. At the other end the concrete was taken up in a bucket inside an 80-ft. tower, tipped automatically into a steel hopper, and distributed by a chuting plant.

For the roof over the shop, which is 35 ft. above the ground level with another 8 ft. for the skylight, special consideration was given to the shuttering and scaffolding. Under the flat roof the shuttering was carried by steel joists, one under each beam supported from the crane girders and propped up in the centre by 4 in. by 9 in. planks. The shuttering for the slab, being made up in panels and having sufficient materials to form the shuttering for four bays, could be made use of many times over and easily shifted about. Special travellers were constructed from



New Workshops for the Gas Light & Coke Co.

New Workshops for the Gas Lig it & Coke Co.: Mess Room.

steel joists and channels with wheels to run on the crane rails temporarily laid down for the purpose, and off these the shuttering for the trusses was supported. When ready for striking the shuttering was lowered by simply knocking out wedges, and the whole arrangement (scaffolding and shuttering) could be wheeled forward without further dismantling. The purlins were pre-cast on the ground, stacked till well matured, and then hoisted into position. Later they were joined up by concrete filled into the space between them, the ends being shaped so as to form a key, steel projecting from the trusses being embedded in the concrete. The hoisting of the purlins weighing about 1¾ tons each was performed without a hitch. Facilities were obtained by using a travelling gantry spanning across one roof-light and fitted with wheels travelling on the crane rails, which for that purpose were made use of temporarily on the roof.

The greater part of the building was concreted during the hot weather which prevailed during last summer, and great care had to be taken to counteract the effects which otherwise might arise therefrom. A special point was made, for instance, of watering the concrete and keeping it damp the first week after concreting. All floors and roofs were constantly watered, and by covering them up with cocoanut matting they were prevented from drying too quickly. The results were evident. In spite of the great heat the roof has been practically free from shrinkage cracks and the concrete is watertight. In order to ensure watertightness, particularly over the offices, the roof is being rendered with a layer of "Masticon"

The lay-out of the building has been planned by the Gas Company's staff at Beckton, under the direction of the Resident Engineer, Mr. W. B. Leech.

The design and detail drawings for the ferro-concrete work were prepared by Messrs. Peter Lind & Co., of 2, Central Buildings, Westminster, S.W., who were also general contractors for the whole of the building work.

REINFORCED CONCRETE AND FIRE-RESISTANCE.

I—INSURANCE AND INSPECTION.

By J. SINGLETON-GREEN, B.Sc. (Hons.Eng.), A.M.C.I., M.Am.C.I.

THE MEANING OF FIRE-RESISTANCE.

At the outset it is essential to appreciate the fact that there is no such thing as a "fireproof" building. "Fire-resistance" is the correct term to use, and this is obviously a question of degree. The term "fireproof building" so generally used is a dangerous appellation, as it instils in the minds of the occupants a false sense of security that often leads to a neglect of those simple precautions which are so necessary, and which, if the building were labelled "non-fireproof," would be carefully observed. Another important point is the degree of fire-resistance. This resistance may be reasonably sufficient for ordinary conditions, but wholly inadequate against the intense heat from the combustion of a great quantity of inflammable materials that may be stored in it. The growing tendency to store masses of merchandise in buildings makes buildings of higher fire-resistance necessary.

It frequently happens after a fire that the walls of a structure are still standing and are taken as an evidence of the fact that the building has satisfactorily passed the conflagration. Often the concrete walls are not damaged by the fire; and in one instance everything required renewal (floors, doors, windows, and roof) except the concrete walls. People looked at that building, with its walls of concrete, and said, "Why, it is a first-class fireproof building!" The value of the structure that remained was perhaps 10 or 15 per cent. of the cost of the building—85 or 90 per cent. had been destroyed. It was not the fault of the concrete. The doors, windows, partitions, floors, and roof were all of wood, and the building, therefore, was far from being "fireproof." Again, the floors and columns often have a reasonable fire-resistance, but the front walls, which are of cast-iron, are destroyed, or the walls of brick wholly or partially collapse. This is illustrated in the Guarantors' Trust Company's building at Baltimore, one of the best examples in America of the behaviour of reinforced concrete in a serious conflagration. Load tests were applied to the floors after the fire by the Municipal Department of Buildings, and they were found to be amply safe under the building laws.

In the discussion on Mr. Humphrey's paper ("Fireproofing"; Concrete Institute, October, 1911), Mr. Etchells pointed out that it is now generally recognised that fire-resistance itself is merely a relative term, and with a high enough temperature any material will melt. The highest temperature commonly obtained is about 4,000° C. in the electric arc. Very few materials would stand that; but it is not necessary to go to high temperatures to get danger. Granting that the best form of fire-resistance is obtained from a correctly-designed reinforced concrete building, it is evident that if the fire is large enough and the temperature high enough the building will fail at some point. This immediately shows that other factors have to be considered besides the actual quality and nature of the concrete, some such facts being the height of the building, the nature of the storage, windows, vertical shafts, and partitions. These points will be discussed later.

It must be remembered then that—

(1) There is no such thing as a "fireproof" building.

(2) Every building (whatever its nature or construction) has a certain "fire-resisting" capacity. Of course, compared with a modern reinforced concrete factory, an old and dry wooden shanty would have a very low degree of fire-resistance, but it is still a question of degree. This is the crux of the whole matter, and is of vital importance alike to the owner, the engineer, and the insurance company.

INSURANCE.

The matter of insurance is a vexed question, and requires serious consideration. Insurance companies should vary their rates of insurance for reinforced concrete buildings according to the nature of the design and the method of construction. One reinforced concrete building might have an exceedingly high degree of fire-resistance, whilst another would not be able to withstand even a small fire. But both are reinforced concrete buildings, and, therefore (within limits), the same rates of insurance are applied in each case. This is a wrong system—but how is the matter to be altered? It seems to call for joint action between architects, engineers (including contractors, etc.) and insurance companies. With lower rates of insurance the companies would demand a certain definite standard of workmanship, and this implies constant inspection throughout the course of a job. This is the kernel of the whole business: skilled supervision—with guarantees. Obviously, this cannot be settled either by architects, engineers, or insurance companies alone—joint action is necessary.

In a contribution to the discussion on the author's paper on "Concrete and Fire-Resistance" (read before the Institution of Civil Engineers, Manchester and District Association, on February 22 last), Dr. Oscar Faber, O.B.E., made the following remarks:—"One of the points about fire-proofing which has always struck me as somewhat inconsistent is that the same fire-proofing is asked for under most building by-laws for a warehouse intended to be stocked from floor to ceiling with highly-inflammable goods, as for, say, an engineering workshop where beyond a few benches and stools there will be nothing inflammable whatever, and in modern practice even the benches and stools are ceasing to be of timber. Under London County Council regulations for steel-frame buildings, for example, though different floor loads are specified as between warehouses and factories, no differentiation whatever is made between the fire protection according to the use for which the building is intended. This has led to anomalous results, and what is now required is probably in excess of what is desirable in some cases where the fire risk is negligible and grossly insufficient properly to protect buildings that are really highly inflammable."

In the issue of *Concrete* (U.S.A.), for May, 1921, it is pointed out that so far as the art of building to resist fire has progressed, concrete gives a maximum of protection. The point to remember is that there are degrees of fire-resistance. Obviously the greater the degree of fire-resistance the more will be the precautions necessary and, to a certain extent, the greater the expense. In many cases, however, the extra trouble and expense will not be gone into until insurance companies recognise that there are different degrees of fireproof construction, even where reinforced concrete is concerned. That there are very wide variations in the degrees of fire-resistance is shown both by tests and by actual conflagrations. It must be remembered that concrete is not a standard material, but depends not only on the materials of which it is made but also on who makes it.

Here are the comments of an American fireproofing engineer:—"Engineers in general have very little incentive to pay attention to such recommendations as have been made by the Committee on Fireproofing (American Concrete Institute). Those of us who have been making a study of the fire-resistance of concrete will simply have to have patience and reconcile ourselves to the fact that until the underwriters place a premium on superior fire-resistance in concrete construction engineers and builders will probably go on doing about as they have been doing. As a result, the number of buildings in which such damage as in the Far Rockaway fire and others can easily occur will go on increasing in almost geometric proportion. I must say, however, that the underwriters are probably paying more attention than any other class of men to the information that has been obtained within very recent years from fire tests and other sources on this subject. If the insurance people will only give credit for the more fire-resistive types of concrete construction, so that there will be an incentive for builders to put a little more money in a building for the sake of attaining superior fire-resistance, particularly where the hazards are unusual, these recommendations that have been made in recent years may do some good."

FIRE IN WAREHOUSE OF IMPERIAL TOBACCO COMPANY.

A fire in the reinforced concrete skeleton-frame warehouse of the Imperial Tobacco Co., Norfolk, Va., in June, 1919, left a mass of wreckage, which demanded a considerable amount of explanation. The following extract from a memorandum sent to members of the National Board of Fire Underwriters, by Mr. Ira H. Woolson, Consulting Engineer of the Board, makes one point vitally clear: namely, that continuous inspection of all reinforced concrete work during construction is essential. If architects, engineers, contractors, and owners will not appreciate this fact, then sooner or later it will be brought forcibly into the foreground by the actions of the insurance companies. A report of the same fire, by Mr. A. M. Schoen, Chief Engineer, South Eastern Underwriters' Association, draws similar conclusions.

The following is an extract from Mr. Woolson's Memorandum :—

"The building was principally of reinforced concrete, and in its design and construction appears to have violated nearly all the fundamental requirements for a first-class structure of its type. The placing of reinforcement was bad, and its protection frequently deficient. The quality of the concrete was poor. Some of the coarse aggregate was too large to permit proper distribution among the reinforcing bars. The mixing was carelessly done, as evidenced by the fact that in places there was a large surplus of sand and elsewhere of stone. Proper care was not exercised to ensure continuity between concrete deposited at different times, and the appearance of the concrete also clearly indicated that some of it was deposited too dry and other portions too wet. With these evidences of bad workmanship apparent, and reasoning by analogy, it would not be surprising if the proportioning of all the concrete ingredients was faulty. Unfortunately this could not be ascertained.

"In addition to the foregoing and other imperfections in the manufacture of the building, it possessed several other defects which seriously increased its fire hazard. Open stair-ways and elevators throughout the building transgressed a basic principle of fire prevention, and the imposition of a wooden-constructed story enclosed with sub-standard brick walls over the roof of the original building, and having a large exposure of thin glass in a wooden monitor, was an inexcusable folly. The point of all this is that there was a complete collapse and a large financial loss when the building, generally accredited as a high-class construction and a comparatively safe risk, especially as regards the structure itself, was attacked by fire. This fact involves a lesson which the National Board of Fire Underwriters believes should be vigorously impressed upon the minds not only of the insurance companies for whom these reports were prepared but also upon the owners of such buildings, the architects who design them, and the constructors who erect them. Considering the combustible contents, the lack of sprinkler equipment, and the absence of protection to vertical openings, it was a foregone conclusion that this building would suffer a complete burn-out if a fire in any story were to get beyond control. These conditions were doubtless recognised by the insurance inspectors who examined the building, and the risk was probably rated accordingly, but no such inspection of a completed building could have disclosed the fact that it was so inherently weak in its composition that destruction of its contents by fire would cause a complete disintegration of the whole structure.

"The important thought accentuated in the report, and which we desire to emphasise, is the absolute necessity for continuous competent supervision of reinforced concrete buildings during erection to ensure that all details of safe construction are properly observed by the workmen. The Building Code of the National Board of Fire Underwriters (U.S.A.) directs particular attention to the necessity for such inspection in Section 161, which reads in part as follows :—'*Inspection.*—Every reinforced concrete building shall be erected under the constant supervision of a reputable and competent inspector furnished by the owner or architect, and acceptable to the superintendent. It shall be the duty of the inspector to keep a daily record of the work done, to observe whether the materials employed and the methods of construction are in all respects in accord with the specifications filed with the superintendent and the requirements of this Code; and to make record of all variations therefrom. A copy of these daily reports shall be filed with the superintendent, who is empowered to stop any improper construction until its faults are corrected, or to cause the removal of any defective work which he may consider dangerous.'

"A well-constructed concrete building should not fail as this one did, and every time such a disaster occurs it casts an undeserved slur upon that type of construction. This should stimulate all conscientious architects and builders interested in it to use their influence to compel competent inspection during construction not only as a safeguard for the owner but as a protection to their own business reputation. If insurance companies who are asked to assume the fire risk on such buildings could be furnished with a report indicating competent inspection during erection, and certifying that the plans and specifications had been properly executed, it would go a long way towards removing doubt and the tendency to penalise which otherwise is liable to exist. The importance of this matter has been frequently overlooked in the past, and it is high time that it should receive serious recognition. The expense of such inspection would add a very small percentage to the cost of the building, and it should be considered just as legitimate a cost item as the construction of the roof. Quite apart from any advantage accruing to the owner or insurance interests from such inspection, the general public safety and application of the principles of conservation should demand that every municipal building code contain a clause similar to the one herein quoted requiring such building supervision.

"It should not be inferred, however, from the foregoing arguments that reinforced concrete buildings are the only ones which require such inspection. Bad workmanship is just as liable to occur in other types of buildings, and the necessity for watchfulness in them is also important. The integrity of a brick wall subjected to fire depends more upon the quality of the mortar used, the proper bonding of the brick, and the filling of voids in the middle of the wall with mortar, than upon uniformity in quality of the brick, although the latter is important. Defects of this character would not appear in a finished wall, and there are many other places where seriously-defective construction would be hidden from view in a completed building. With the existing tendency toward careless and indifferent workmanship in general, the obligation for supervision is imperative in all important building work."

Mr. Schoen's report comes to the following conclusions :—

"Possibly no building of so-called 'fire-resistive' construction containing large values that has been destroyed by fire has offered more instructive lessons in the dangers to be apprehended from poor construction, and photographs were taken with a view to bringing out the weaknesses that led to this very heavy fire loss. Unquestionably reinforced concrete can be mixed and moulded to form the highest type of fire-resistive building, but the various items essential to such construction must be accurately and thoroughly met. These are primarily, of course, proper engineering design, based on the calculation of stresses and strains to which the building may be subject under extreme conditions, and the provision of a suitable factor of safety, resulting in the determination of the size and shape of steel reinforcements to be used and the forms of columns, beams, girders, and floor slabs. This and the determination of the proportions of cement, sand, and rock, as well as their character and test, are strictly matters for the designing engineer, and can be readily checked at any time from the blue-prints and specifications kept on record. The mixing, hydrating, and pouring, however, are in the hands of the builder, and in a completed building no record of these can be obtained. Consequently the only protection against improper and unsafe work in this direction lies in careful inspection by competent inspectors while the work is under construction.

RULES AS TO REINFORCED CONCRETE CONSTRUCTION.

Buildings constructed with concrete reinforced in every part with embedded metal rods or bars spaced not more than 12 in. apart, securely connected or overlapping at least 6 in. at all abutments and intersections, having also bands or bars across the thickness of the concrete, may be deemed of Standard I*a* Construction, provided they conform to the above Rules (see General Rules), with the following modifications :—

Rule 3.—Concrete may be composed of

sand and gravel that will pass through a ¾ in. mesh, or of the other materials mentioned in the Rule, but in any case the cement used must be Portland (equal to the British Standard Specification of December, 1904) in the proportion of 6 cwt. of cement to each cubic yard of concrete. The concrete must be thoroughly mixed both dry and wet, and must be rammed round the metal work in position, every part of which must be completely enclosed with solid concrete.

Rule 4.—No external wall to be less than 6 in. thick in any part, and no division wall less than 8 in. No party wall to be less than 13 in. thick in any part, unless the adjoining building be of reinforced concrete construction in accordance with standard I*a*, I*b*, or I*i*, in which case 8 in. is allowed.

Rule 7.—Flues may be built of reinforced concrete as described, not less than 4 in. thick; if lined throughout with fire clay tubes not less than 1½ in. thick. No timber or wood-work to be in contact with such flue.

Rules 10 and 11.—Floors must be constructed of reinforced concrete as described not less than 5 in. thick in any part without woodwork bedded therein, supported on beams and columns of similar reinforced concrete.

Rule 13.—Roofs must be constructed in a similar manner to floors, the concrete in no part to be less than 3 in. thick.

Rules 14, 15 and 16.—All structural metal work must be embedded in solid concrete, so that no part of any rod or bar shall be nearer the face of the concrete than double its diameter; such thickness of concrete must be in no case less than 1 in. but need not be more than 2 in.

Rule 18.—Enclosure to staircase and hoist, if of reinforced concrete as described, may be 6 in. in thickness.

Rule 22.—Fireproof compartments in connection with reinforced concrete structures must also be of reinforced concrete as described, with walls not less than 8 in., and floors not less than 5 in. in thickness.

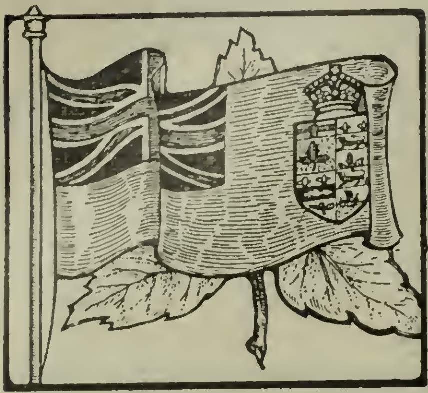
[The above rules are given by permission of the Fire Offices' Committee.]

[*** An article dealing more generally with this subject appeared in our January issue.—Ed.].

MELTON CONSTABLE WAR MEMORIAL.

This memorial takes the form of a pillar of classical design with panel plastered face, also a cast bronze plate with the names of the fallen and inscription "To our glorious dead. Their name for ever liveth." The pillar is supported on each side by piers and ornamented supports, the whole being mounted on radiating steps, giving a total height of about 9 ft.

The pillar is capped with a moulded entablature and blocking-course on the frieze, on which is the date "1914–1918" and a carved laurel wreath rests on the blocking-course above the frieze. The structure is built of large cast concrete blocks. The memorial was designed in the office of Mr. W. Marriott, M.Inst.C.E., Engineer and Traffic Manager of the Midland and Great Northern Railways Joint Committee, Melton Constable, and executed in the railway workshops in that town.



THE NEW REINFORCED CONCRETE TRAFFIC BRIDGE AT SASKATOON.

THE construction of this bridge was undertaken by The Board of Highway Commissioners in conjunction with the city of Saskatoon. The bridge is a reinforced concrete structure consisting of ten spans, the smallest 25 ft. and the largest 150 ft. The roadway is on a 2·88 per cent. grade. The total floor width is 65 ft., including two 8 ft. side walks. The arches consist of two rings 16 ft. wide and 15 ft. apart. The floor system is supported on these by spandrel walls and columns, and is made up of beams and girders. The work was commenced in August, 1913, from which date up to April, 1914, all piers with the exception of two of the river piers, west side abutments, and west side retaining walls, were completed. The concrete of the piers (with the exception of two) was not carried to the springing line. Work ceased some 8 ft. below the springing line. During the season of 1914 and 1915, the remaining two river piers were completed, together with all the arch rings of the bridge. At the beginning of the season a great deal of work had to be faced, as it was necessary for the safety of the work that all the arch rings should be completed before the cold weather set in. The first two arches were poured in June. These were the two small arches on the west end, consisting of 25 ft. and 66 ft. spans. The material for these was mixed in a batch mixer, and delivered by means of a tower and elevator. The third arch,

REINFORCED CONCRETE BRIDGE AT SASKATOON.

Reinforced Concrete Bridge at Saskatoon.

the segmental one at the east end, was not poured until August, and it was from that date until the 13th of November that the remainder of the arches were poured. The last arch was run on the 13th of November. The last two arches required heated materials and special attention to safeguard them against the severe weather. From the month of August the concrete was mixed by a machine furnished by the Pneumatic Concrete Placing Company, and we understand that this is the first work in Western Canada on which this system has been used. The method of mixing is very simple. Measured quantities of aggregate, cement and water are placed in a close metal chamber, and air compressed to 110 lb. per square inch is introduced at various apertures in the chamber. The material mixed in transit is then forced under this air pressure through a pipe 8 in. in diameter into a discharge box from which it is led into the work. The completion of the arch rings finished the season's work. This left the superstructure to be completed. The inability to complete all piers during the winter of 1913 and 1914 seriously delayed progress and left barely time to finish the arch rings before the cold weather closed down the season of 1914.

In May, 1915, the erection of formwork and placing of steel for the floor system commenced at the west end, and was carried ahead over three arches before the pouring of concrete began. The latter end of June, 1915, saw concreting in progress and by the 2nd of August the floor system over five arches had been poured, and the formwork over the four remaining arches was well advanced.

For greater safety, the loading due to the floor system was brought symmetrically on to each arch, by commencing at its crown and working out towards the haunches.

REINFORCED CONCRETE BRIDGE AT SASKATOON.

In August, too, part of the east approach retainers adjoining the abutment had been poured. Thereafter, equally good time was made on the work, and by November, 1915, the floor system and eastern approach retainers had been carried to completion, formwork had been lowered, and the bridge stood out in its entirety.

During the progress of the floor system it had been found desirable to alter the reinforcement in some of the floor beams, and this was done without difficulty.

To meet a variation of 13 in. in length due to temperature changes, sliding plates approximately 42 ft. apart longitudinally and 14 ft. apart laterally were used throughout the floor system, and some trouble arose at these plates when the winter contraction set in. It is believed, now all the plates have taken their initial movement, that this trouble has been satisfactorily met and overcome, and no repetition of it is apprehended.

At the close of the working season, the finish to exterior surfaces, the completion of side walls of conduits under floor, the filling in of the eastern approach and some general trimming up remained to be done. At the city's request an extension of conduit at each end of the bridge had been sanctioned, and these extensions, totalling about 140 ft. in length, also remained to be done by the contractors.

The dimensions of the bridge are :—

Total length of bridge proper	1,200 ft.
Length, including approaches	1,467 ft.
Width of roadway	45 ft.

In addition there are two cantilever sidewalks, each 8 ft. 6 in. in width.

There are ten arches, increasing in size from the west bank to the east bank of the river, the largest arch being a 150 ft. span.

There were 2,000,000 lb. of steel and 23,000 cubic yards of concrete used in the work.

The work was commenced in September, 1913, and the bridge completed, with the exception of the roadway paving, in November, 1915.

Part of pier "JK" immediately below the springing line of arches failed to take a proper set, and it was found necessary to remove the faulty material. The wedges holding the centering in place were kept firmly in position under the adjacent arches, and the poor material was removed in parallel strips running longitudinally through the pier. A very thorough and workmanlike job was made of this difficult repair. The spillway consists of a reinforced concrete lock joint pipe with finished ends well protected on the upstream side with rock riprapping. In addition to this a reinforced concrete culvert, 8 ft. span, takes the surplus water at times of flood.

LIGHT CONCRETE ROOFS.

THE increasing demand for light roofs of large span has been the cause of frequent attempts to use concrete for this purpose. One of the most satisfactory methods of doing this is to lay the reinforcement on the shuttering and then to apply the concrete

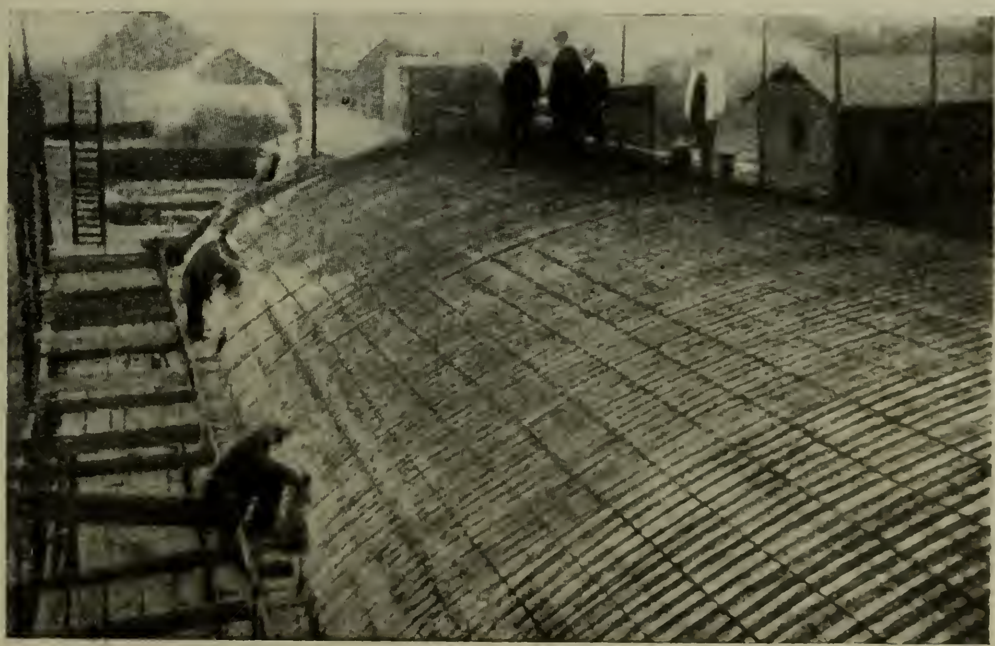


FIG. 1. LIGHT CONCRETE ROOF AT HOMBERG.

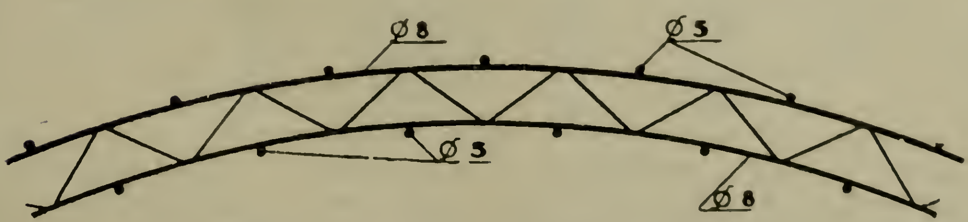


FIG. 2. REINFORCEMENT FOR LIGHT CONCRETE ROOF.

externally, as in *Fig.* 1. If the reinforcement is arranged as shown in *Fig.* 2 it will be stiff enough to walk on with safety. The diameter of the chief reinforcing members is shown in millimetres in *Fig.* 2.—*Beton ü Eisen.*

THERMAL CONDUCTIVITY OF CONCRETE.

There is still much scope for the accumulation of physical data connected with concrete, and in Bulletin No. 122 of the Engineering Experiment Station of the University of Illinois is to be found some useful information dealing with the thermal conductivity and diffusivity of concrete, as measured by Messrs. Carman & Nelson.

The method of measurement adopted was to cast concrete cylinders 24 in. long and 7½ in. diameter with a hole 1½ in. diameter through the centre and three other holes $\frac{5}{32}$ in. diameter parallel to and at different distances from the axis. A heating coil was inserted in the central hole and thermo-couples in the smaller holes. The observations comprised the heat (amperes and volts) admitted by the coil and the temperatures registered by the thermo-couples at three distances from the heating coil. In order to obtain consistent readings, it was found necessary to dry out the concrete by heating the cylinders to 212° F., and the heating by the coil had to continue for from 14 to 16 hours before the temperature became constant for observations to be taken. The aggregates used were gravel and sand of dolomitic limestone origin.

The thermal conductivity was calculated for two sets of units, first, the C.G.S. unit, corresponding to the flow of one gram-calorie in one second when the flow is steady, through a section of a plate of the concrete under test one square centimetre in area and one centimetre in thickness, the difference between the temperatures of the faces being 1° C.; and second, the British Engineering Unit corresponding to the flow of one B.T.U. in one hour through a plate 1 sq. ft. in area and 1 ft. thick with a difference of 1° F. between the temperatures of the faces of the plate.

The equation used for the calculations was—

$$K = \frac{Q}{2\pi l (t_1 - t_2) T} \log \frac{r_2}{r_1}$$

Where K = thermal conductivity.
Q = quantity of heat passing.
l = the distance of flow of heat.
$t_1 - t_2$ = difference in temperature between points at radial distances r_1 and r_2 respectively.
T = time of flow.

A summary of the results obtained is given in the following table:—

Average Thermal Conductivities of Different Mixtures of Concrete, and of Marble, at Different Temperatures.

Mixture By volumes.		50° C. to 100° C. 120° F. to 212° F.		100° C. to 200° C. 212° F. to 390° F.		200° C. to 300° C. 390° F. to 570° F.	
Cement : Aggregate.	Cement : Sand : Gravel.	k c. g. s. Physical.	k British Engineering.	k c. g. s. Physical.	k British Engineering.	k c. g. s. Physical.	k British Engineering.
"Neat"		0·00140	0·339	0·00163	0·394	0·00140	0·339
1–2	1–1·2–1·1	0·00326	0·789	0·00344	0·832	0·00318	0·770
1–3	1–1·9–1·7	0·00335	0·811	0·00379	0·917	0·00318	0·770
1–4	1–2·4–2·3	0·00413	0·995	0·00352	0·852	0·00328	0·794
1–5	1–3·1–3·0	0·00327	0·791	0·00323	0·782	0·00334	0·808
1–7	1–4·3–4·0	0·00400	0·968	0·00384	0·929		
1–9	1–5·6–5·1	0·00574	1·39	0·00352	0·852		
Marble		0·00614	1·49	0·00493	1·19		

The results show that neat cement had a much lower thermal conductivity than concrete, and on seeking for the cause of this difference it is observed that while the neat cement contained about 42 per cent. of voids as calculated from its weight of 114 lb. per cu. ft., the concretes of various mixtures contained from 16 to 20 per cent. of voids corresponding to weights per cu. ft. ranging from 135 to 143 lb. Solid marble shows the highest conductivity of all. The proportion of voids is probably the prime factor in determining the conductivity of concrete, and it is obvious that the investigation of this subject offers scope for development in compiling data for concretes of various aggregates and various densities.

The results now reported for thermal conductivity of concrete are considerably higher than those previously published, but the later results being deduced from some hundreds of tests on fifty different cylinders are worthy of acceptance for the aggregates and mixtures tested.

CONCRETE ON ARTERIAL ROADS.

Under the able direction of Mr. Alfred Dryland, M.Inst.C.E., County Engineer of Middlesex, that part of northern London which lies within the County of Middlesex should soon be in possession of as fine a network of roadways as any part of the country. The new roads which are being built there are constructed on various systems, but throughout all the work there is evident an endeavour to ensure that the roads shall be as permanent as it is possible to make them, rather than to obtain within a short time a large mileage of roads with regard to the future stability and lasting qualities of which there might be any doubt. This is exemplified in the section of the Great West Road that falls within the county which, at a cost of nearly £200,000 a mile, will compare with, and probably surpass, any other road in the world as regards strength and durability.

In the attempt to obtain the best return possible for the capital outlay reinforced concrete roads are being fairly extensively laid down. One of this type of road—the section of the Cambridge Road in Edmonton and Tottenham—was described in our July number, and we recently had an opportunity of seeing another such road which is being carried out to the design of Mr. Dryland under the supervision of Mr. F. Wilkinson, M.Inst.C.E., Engineer to the Willesden District Council. This section, which forms part of the new North Circular Road, runs from Harrow Road to Edgware Road, and is being built somewhat on the same principles as the Edmonton road—that is, provision is made for a road 100 ft. wide, of which 50 ft. is now being developed with a 24-ft. carriageway and two footpaths, each 8 ft. wide. Ultimately it is proposed to construct two such roads within the 100 ft., running parallel, so that the road will consist of two 24-ft. carriageways for traffic going in opposite directions and a space left in the middle for a tramway track if required. The section which is being carried out in bare reinforced concrete is being built in three parts, of which one part of three-quarters of a mile is now in use, a further section of 1½ miles is nearly completed, and one centre stretch to connect the two is yet to be re-built. The road consists of 8 in. of reinforced concrete on a layer of well-burnt clinkers, and no expansion joints are used.

To quote our contemporary, *The Surveyor*, " The surface of the completed sections is remarkable for the fewness of the cracks which have appeared ; there are no longitudinal cracks whatever, and the few transverse cracks are so small as to be negligible so far as the road user is concerned. The first section was opened to traffic at Whitsun, and, in spite of the heavy traffic which has since passed over it, the surface appears to be as good as when first laid." This road will take the bulk of the traffic to Wembley in connection with the forthcoming British Empire Exhibition, and an excellent test as to its traffic-bearing capacity will thus be presented in the near future. The tamper has been worked so as to leave certain small surface irregularities which afford an excellent foothold for horses, and the experience which will be gained on this road will probably do much to dissipate the idea held in some quarters that bare concrete surfaces are unsuitable for horse traffic. The kerbs are of concrete constructed *in situ*. The reinforcement used is Walker-Weston interlocking on Section I and B.R.C. mesh on Section III, the latter being placed 2 in. from the surface. The surface is protected from the heat of the sun by a covering of earth, which is kept moist by sprinkling water from a hose and removed after two months' seasoning.

The labour for the work is drawn from the ranks of the local unemployed,

New Reinforced Concrete Road at Willesden.

and is doing much to relieve the distress in the district. With the exception of 20 per cent. the men engaged on the excavation and other unskilled work are changed each fortnight, but the skilled men employed on the actual mixing and laying of the concrete are, of course, being kept on throughout the job. These men have become very proficient, as is evidenced by the fact that they are laying up to 180 ft. of roadway 24 ft. wide in a day of 8½ hours. The training of skilled concreters which is thus going on throughout the country will be an important factor in the laying of concrete roads in the near future, for instead of having to train men for each job, as is frequently the case at present, there will be formed a body of skilled men from which expert concreters can be drawn when required. As a result of the excellence of the supervision and general arrangements some remarkable outputs are being obtained from other classes of workers also. For instance, an average of 5 to 6 cub. yds. of clay per man per day has been excavated, and on a very favourable occasion as much as 12 cub. yds. was handled per man per day.

The road appears to have every prospect of a long life with but little cost of maintenance, and this is undoubtedly largely due to the experience and keenness of Mr. Dryland and the enthusiastic work of Mr. Wilkinson and his assistants, in whose area and under whose supervision the road is being carried out. Mr. H. H. C. Fowler is the resident engineer for Section I and Mr. E. Scott for Section III. Several experiments have been made by Mr. Wilkinson to test the density of the concrete, and it has been found that the absorption of the test pieces cut out from the road was only 2 per cent. of water, a close approximation to the absorption properties of natural stone.

Setting Time for Concrete Road Foundations.

The Highways Committee of the Westminster City Council has given consideration to the length of time allowed for the setting of the concrete foundations of carriageways. The practice in the past has been to allow only seven days from the completion of the concrete before permitting traffic to pass over the road, but in the contracts now in progress this period has been extended to ten days. The Committee thinks it very desirable that the period allowed for setting should be increased, as the life of the concrete foundations will be increased thereby. This will particularly be the case where the foundations are of the maximum depth. The minimum period is fixed at ten days, and wherever possible the opinion is expressed that the period should be fourteen days.

ROAD FOUNDATIONS IN ESSEX MARSHLANDS.

By ERNEST LATHAM, M.Inst.C.E.

THE famous oil depôts, wharves, and refineries at Thames Haven, Essex, are probably well known to the majority of our readers. The writer first became acquainted with this district in 1906, when access was of the most primitive character. The nearest railway station is at the little township of Stanford-le-Hope, about six miles by road from the site. Going from Stanford-le-Hope to the depôts of the London & Thames Oil Wharves, Ltd., and the Shell-Mex Co., Ltd., this road traverses high ground as far as the village of Corringham, beyond which it descends rapidly to low-lying marshes adjacent to Sea Reach on the River Thames. These marshes are several feet below Trinity high-water mark, and form part of the extensive system of marshlands lying between Purfleet and Leigh-on-Sea. In 1906 the road known as the Manor Way was of the " prairie " variety, since, after reaching the marshes, it became progressively worse, ending in a " mud-slew." The visitor to Thames Haven was largely dependent on the state of the weather as to how near his horse-drawn vehicle could approach the Thames Haven Depôt before he had to dismount and wade through the mud to his objective ! In those days " Oil Mill Farm " was the road-head even in summer, and the last half mile was traversed by a footpath. All this now belongs to an almost forgotten past, the journey to either depôt from Stanford-le-Hope now consisting of a fifteen-minute taxi ride to any of the principal gates.

The Orsett Rural District Council led the van in so far as finances permitted in a gradual patching-up and improvement of the Manor Way road surface. Early in 1913 it became apparent that, while the oil wharves were served efficiently by river and by rail in the form of a four-mile long siding used for freight traffic only, the development of industry was being seriously handicapped by want of road access, and the London & Thames Haven Oil Wharves, Ltd., determined to construct a private road across the marshes from a suitable point on the Manor Way to their depôt. This work was duly undertaken, and was followed by an extension of the Manor Way to Shellhaven by the Asiatic Petroleum Co. These two new roads and the improved Manor Way now, therefore, form the road system of the district, and serve two oil companies, the new village of Shellhaven, and the Midland Railway goods

FIG 1. SITE OF NEW ROAD.

station at Thames Haven. The greater interest attaches to the construction of the first of these two new roads, since securing road foundations for heavy traffic on these unstable marshes was by no means a simple problem. The road itself was constructed to a width of 32 ft. for a length of 3,170 ft., and was practically " dead level " throughout and some 4 ft. below high-water mark. The public authorities whose sanction to the new road had to be obtained were the Orsett Rural District Council and the Fobbing Level Drainage Commissioners, the first as regards the junction with the Manor Way and the second as regards the conservancy of the marsh drainage channels. The engineers concerned were Colonel R.E. Crompton, C.B., and the writer, the former being responsible generally for the construction of the road as a whole and the latter for the foundations where " bad patches " had to be traversed.

It is necessary to remember how very small is the supporting value of these marshes. The marshes consist of a few inches of surface soil growing rank grass ; beneath this a dense clay occurs, but at varying levels down to 12 or 14 ft. below the surface is a band of peat from 1 to 5 ft. thick. This peat is always waterlogged, and borings show that immediately the bore lining is removed water rises to within a foot or two of the surface. In addition, the marshes are intersected by dykes and fleets, the latter being ancient creeks now severed from the river estuary, but containing mud to a great depth. *Fig.* 1 shows the site of the new road. From this it will be seen that after leaving the public highway the road runs south, crossing the Corringham Light Railway by means of a level crossing. The course of the road then follows that of the light railway, running alongside the latter for most of its remaining length. It was decided not to disturb the surface vegetation in any way, this being regarded as a useful matrix on which to spread the road bottoming, consisting of clinker, broken brick, etc. Colonel Crompton was insistent that each layer should be efficiently rolled to reveal " slacks," and that these should be made up before the next layer was spread. This formation was topped with coarse pit gravel, and rolled. Fine gravel was then spread, and the surface finally " blinded " with hoggin. The road has since been tarred over and remains to-day in excellent condition.

During construction several bad patches were encountered, and absorbed many more cubic yards of material than had been anticipated. It is perhaps useful in this respect to issue a note of warning to engineers and contractors in respect of this type of road. The conditions of contract should not, as is usual, determine payment to the contractor on a schedule rate applying to cubic yards of hard core or filling as ascertained by measurement after formation ; the writer has known cases where this has led to considerable dispute. Where soft marsh land is involved as distinct from " dry " ground there is only one equitable mode of payment, and that is on cubic quantities delivered in respect of the contract. The construction of the road necessitated the building of two culverts, one a simple matter while the other presented considerable difficulties. The road crosses Oil Mill Fleet alongside the Corringham Light Railway, the latter being carried on timber piles with a timbered culvert in the centre of the fleet. The fleet at this point was about 120 ft. wide, and this severance of the road into two sections was a source of difficulty to the contractors as, until either a temporary gantry could be thrown across or the permanent work carried out, the southern portion of the road site remained isolated. As a temporary gantry would have been very costly owing to the great depth of mud in the fleet it was decided to tackle the permanent work at this point first. The design of the culvert was referred to the Considère Construction Company, who prepared the detailed plans. The general outline of this design is given in *Fig.* 2, the hydraulic section being specified by Mr. A. E. Carey, M.Inst.C.E., Engineer to the Drainage Commissioners. From this illustration it will be seen that the culvert is virtually a bridge carried on reinforced concrete piles with interlocked reinforced concrete sheet piles forming the abutments. This work was carried out by Messrs. George Munday & Sons, contractors.

This culvert was the principal problem in connection with the road, and the design was varied many times before finality was reached. It was at first proposed to get the necessary support by flotation on the mud by utilising a hollow concrete caisson, but this idea was condemned on the grounds of possible tilting should the mud prove of unequal consistency ; then piling was determined on, but a test pile gave most disappointing results, going 31 ft. 6 ins. into the mud before a $\frac{1}{2}$ in. set was reached

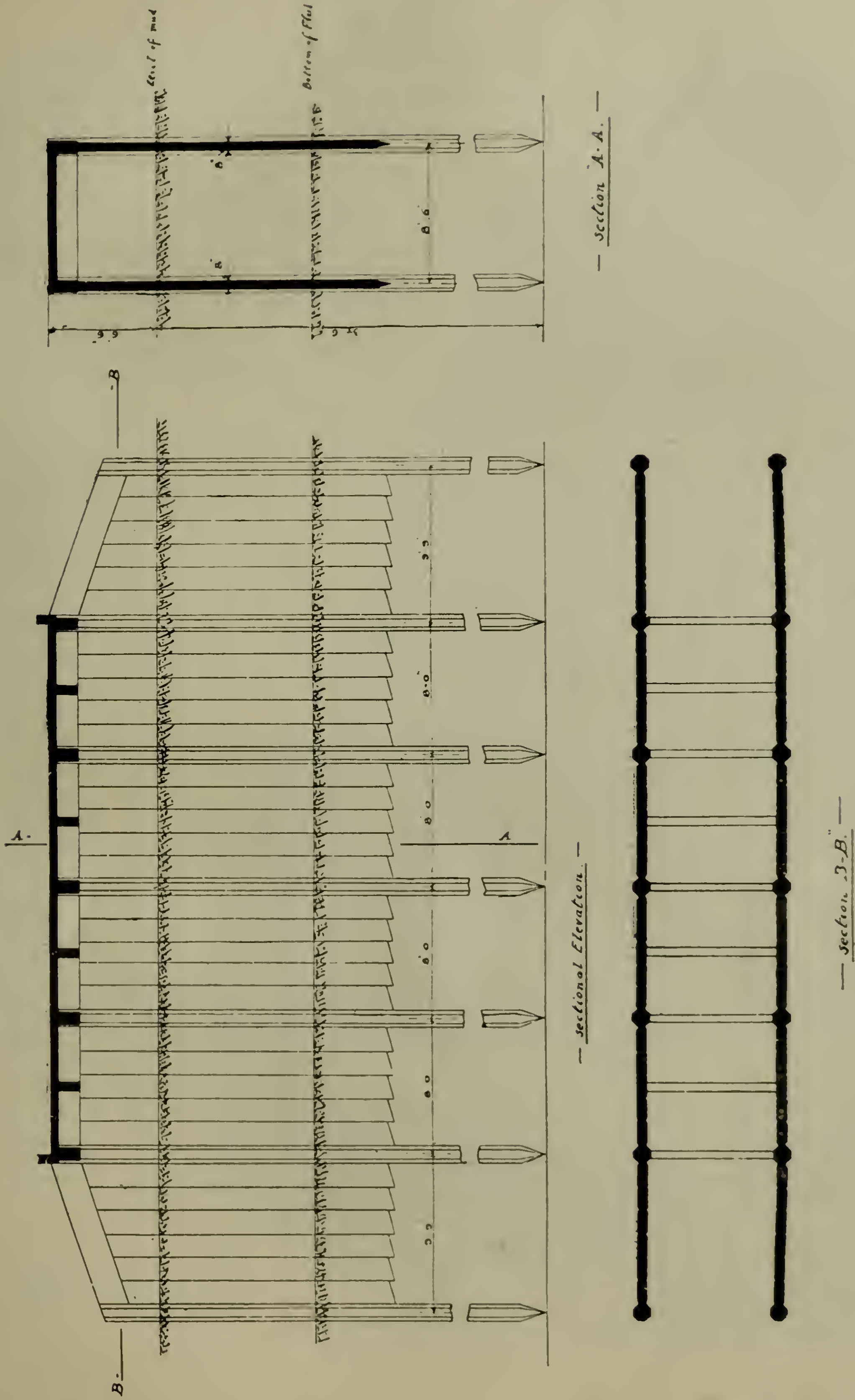


Fig 2. Culvert over Oil Mill Fleet.

ROAD FOUNDATIONS IN ESSEX MARSHLANDS.

with a 27 cwt. hammer, 6 ft. fall. The design had again to be modified and the main piles lengthened. It will thus be seen that crossing an innocent-looking little "gut" in marshy country is sometimes not such a simple matter as it seems. The road formation was brought up to the abutment walls by tipping block-chalk embankments from the road head, involving 23,490 cubic ft. of block-chalk. The actual cost of carrying the road over this fleet was approximately £900, or over £22 per yard forward without any allowance for road materials, metalling, etc. To cross such a bad patch to-day would probably cost twice as much.

One interesting point was the setting-out of this work. *Fig.* 3 is the setting-out plan. It had originally been intended to run the road straight across, but the "S" curve formation had to be adopted to locate the new culvert as near as possible in the centre of the fleet and for cleansing purposes to keep it clear of the culvert under the Corringham Light Railway. The latter culvert had to be accessible for repair purposes, and in any event could not be extended westward on its existing alignment owing to the northward trend of the Oil Mill Fleet. The contractors for the road formation work were Messrs. G. Hayward, and the work was commenced in May, 1913, while the road was open for traffic early in 1914 and has been continuously open since, receiving much hard wear during the war.

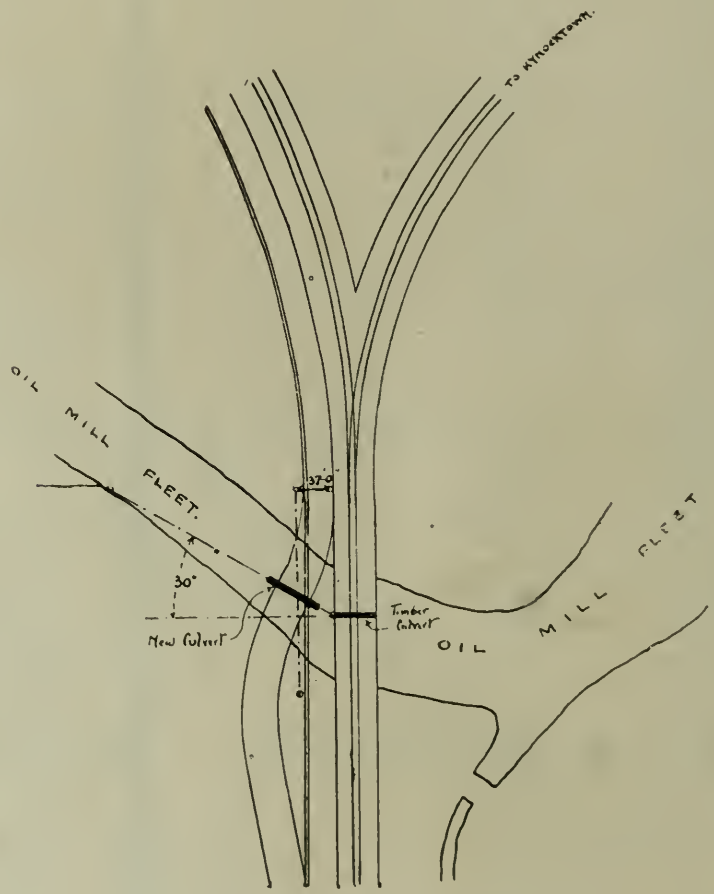


Fig. 3. Setting-Out Plan.
Road Foundations in Essex Marshlands.

New Boot Factory at Leicester. (See p. 596.)

[Mr. Howard H. Thomson, F.R.I.B.A., Architect.

A REINFORCED CONCRETE BOOT FACTORY.

The building illustrated herewith, built for Messrs. Liberty Shoes, Ltd., is situated on the Eastern Boulevard, Leicester, and provision is made for future extensions. The building is 233 ft. long by 45 ft. wide, and comprises four floors, each 12 ft. 6 in. high, each floor being divided into bays, 14 ft. 3 in. square, with columns along the centre line. The total floor space of the factory proper is over 42,000 sq. ft. The ground floor is 4 ft. below street level, the sills of the windows being at the level of the pavement. The top floor is covered with a terrace roof broken by a series of north lights.

The architectural expression has been obtained by treating the structural material with due regard to line and proportion, the only attempt to introduce other features having been in the use of brick bays in the principal elevation, built up of Barnett brindle bricks with artificial stone dressings. The panels formed by the reinforced concrete framework between the windows have also been filled in with brindle brickwork.

The reinforced concrete floors are covered with two thicknesses of floor boarding laid on battens, the upper layer being in maple and rift-sawn Oregon pine, thus permitting the screwing-down of small machines and providing a hardwood surface to resist the wear of the small wheels of the boot racks. Slip tubes and bolts, of which there are some thousands, were so arranged and disposed in the shuttering and moulded in the concrete that accurately-placed fixings were obtained for all power transmission appliances, electric motors, heating pipes, sprinkler installation and electricity cables and wires for power and light. Thus the cutting of concrete after construction was reduced to a minimum. To accomplish this end the whole of the mechanical and other equipment of the building was set out in full detail before the work of construction was commenced.

The boiler for the heating plant is situated in a small independent block at the rear of the building, and provides steam at low-pressure for the whole of the installation. The reinforced concrete water tank has a capacity of 7,500 gallons, and is at a height of 70 ft. above ground level, having been erected over one of the sanitary blocks for the purpose of supple-

[*Mr. J. H. Morcom, Sculptor.*

The Figure of "Liberty" on the Boot Factory at Leicester: During Execution.

NEW BOOT FACTORY AT LEICESTER INTERIOR. (See p. 596.)

[Mr. Howard H. Thomson, F.R.I.B.A., Architect.

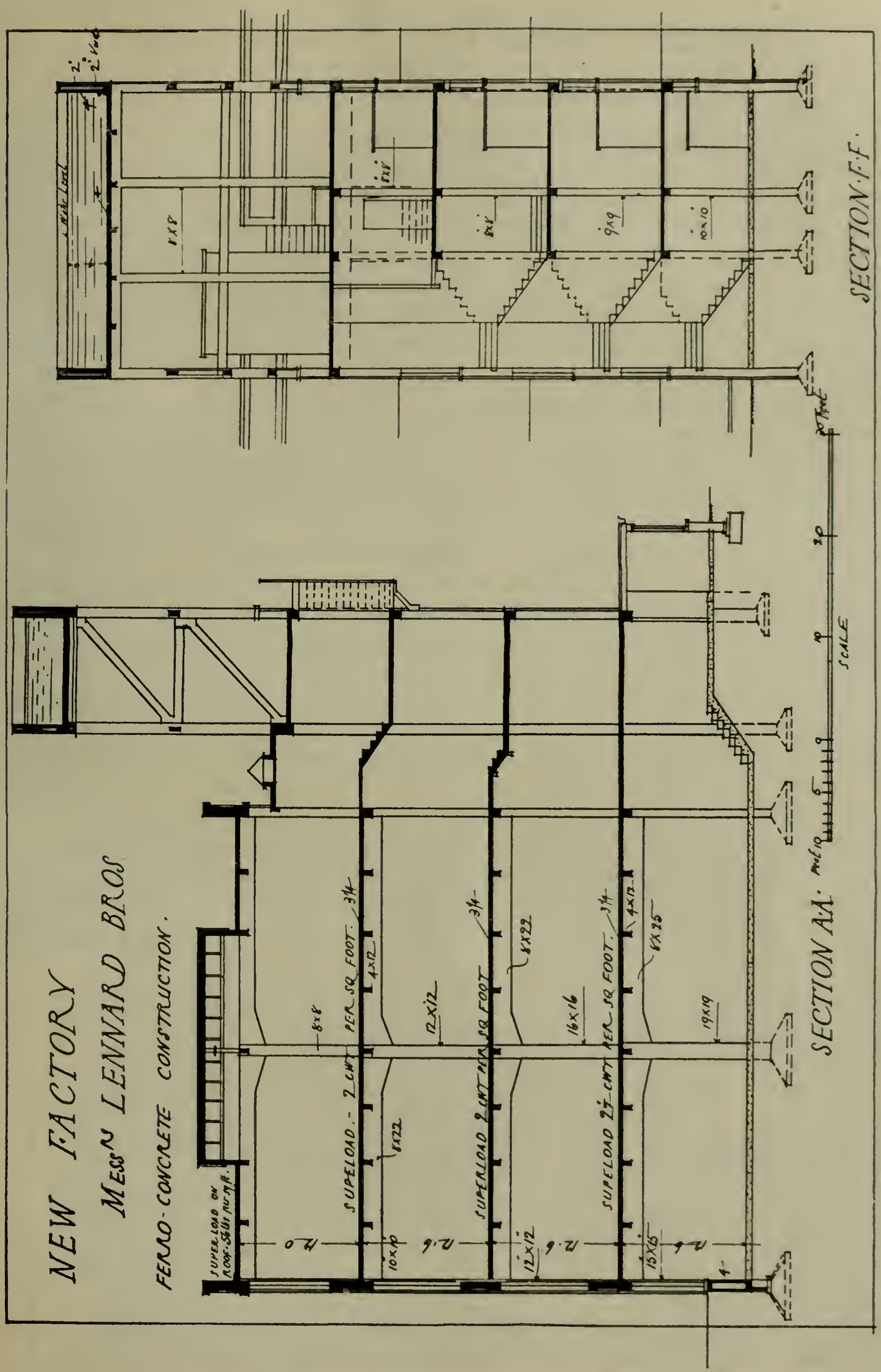
New Boot Factory at Leicester : Top Floor.

menting the supply from the city mains to the sprinklers.

The building was erected in accordance with the plans and designs of Mr. Howard H. Thomson, F.R.I.B.A., details of the reinforced concrete construction having been prepared by Messrs. L. G. Mouchel & Partners, Ltd., of Westminster, S.W.1. The contractors for both the reinforced concrete and the general building work were Messrs. A. Jackman & Son, Ltd., of Slough, and the clerk of works was Mr. William Noakes of London.

THE FIGURE OF LIBERTY.

It is of interest to note that the figure of "Liberty" on the corner of this building is carved from cement. As will be seen from the illustrations (on p. 596) of the figure before completion, it was made in three sections. The main armature of the reinforcement is made of circular bands of L-iron strutted with $\frac{3}{8}$-in. steel bars, to which steel rods were fixed to support the large folds of the drapery. The whole of this reinforcement was covered with expanded metal to the shape required and coated with about 2 in. of cement. Writing in reference to this figure, Mr. J. H. Morcom, sculptor, of Turret Studio, The Newarke, Leicester, who executed the work, states: "Cement for architectural sculpture has great possibilities, as it can be modelled in the plastic state, or cast roughly to shape, and carved as circumstances demand. It also has possibilities of form which would not be practical in stone, and the comparative lightness of sculpture executed in cement is in many cases an advantage—in this case the figure had to be hoisted to the top of the building."



[Mr. Howard H. Thomson F.R.I.B.A., Architect.

NEW BOOT FACTORY AT LEICESTER. (See p. 596.)

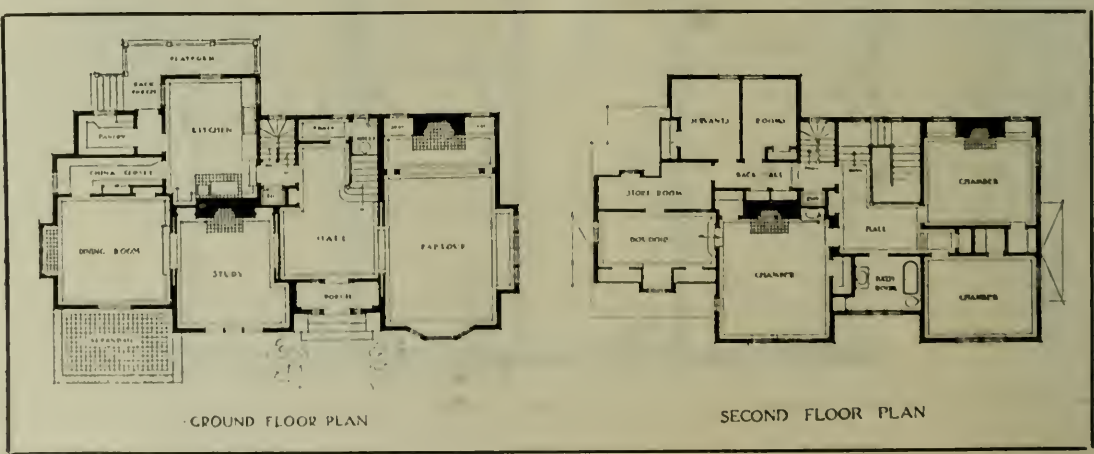
AMERICAN DOMESTIC ARCHITECTURE.

HOUSE AT CAMBRIDGE.

THIS is an interesting example of English domestic architecture grafted on to the American architectural vernacular and built in concrete. The plan is more extensive and grand in character than is suggested by the elevation shown, for it contains three large sitting-rooms in addition to a hall on the ground floor and six first-floor rooms. The American preference for inter-communicating rooms with through vistas has much to commend it æsthetically, and is, of course, a return to older and simpler methods of planning, but it leaves much to be desired from the point of view of convenience, as in this house where the entrance to the dining-room is by way of the study.

Although constructed in concrete, the general appearance of the house suggests a brick, timber, and tile construction, and on this account is perhaps not so successful an example of the concrete design as others which have appeared in these pages. We are without information as to whether the overhang at the first floor is caused by the projection of the floor joists, as the appearance suggests, but if this be not so, an attempt to simulate a timber construction in concrete is to be deplored. Although the elevation composes pleasantly enough, this is an example of that lack of proper harmony between material and treatment to which all good design aspires. There is no reason why concrete should imitate the idiom of other materials, for it can develop its own treatment, or avail itself of those for which it is suitable. The material to which it most nearly approaches is stone, and it can therefore often be used in place of stone without seeming to be clothed in inappropriate forms. This applies particularly to domestic work, which consists so much of ashlaring, but would not be applicable to the arcuation of Gothic work.

This house, then, may be considered as an interesting example of transition, in which the new material not being able to find new and appropriate forms still expresses itself in the familiar terms of brick and timber. Every new discovery can show the same stage. Was not the early motor-car a horseless carriage ?



[*Mr. Charles K. Cummings, Architect.*

HOUSE AT CAMBRIDGE, MASS., U.S.A.

BOOK REVIEWS.

Reinforced Concrete. By R. J. Harrington Hudson, A.M.Inst.C.E.

London: Chapman & Hall, Ltd. Price 16*s*. net.

Probably we all, in our minds, divide books into two classes—those which are worth reading, and those which are not—and we ought to put into the second class all those which do not either (*a*) give fresh knowledge or information, or (*b*) collect already known information and present it in a specially suitable form. Unfortunately a great many books are written which fall into the second class, and therefore it is refreshing to come across one which on both counts may safely be placed in the first class. Mr. Hudson understands his subject well, has worked at it independently, and presents it in a manner which many will find useful and acceptable.

The book is intended to cover the practical as well as the theoretical side—an ambitious task in a single volume of this size — which necessarily severely restricts the space available to either. Mr. Hudson belongs to the younger school of engineers who in the design treat the structure as monolithic, as in fact it is, who realise that a monolithic structure has many advantages, but imposes on a conscientious designer the obligation of investigating the effect of deflection of a member upon the members with which it is monolithic. He realises that there was growing up a tendency to claim all the advantages of a monolithic structure, and yet coolly ignore the stresses—sometimes very great stresses — which the monolithic character of the structure imposed on some of its members, and in fact, to treat it as a jointed structure in the design, knowing well that it would not be a jointed structure in execution.

In his welcome attitude he has, of course, my fullest support and encouragement, for only along such lines will progress be made, though it cannot be said there are not matters which require further research.

The book can be thoroughly recommended, and these notes are only to be taken as suggestions on what are no doubt secondary matters. The continual reference to the L.C.C. Regulations is probably almost overdone, since, when all is said, they leave very much to be desired, though I do not say there are any better.

The inclusion, in forty-three pages, of

Mr. Charles K. Cummings, Architect.

HOUSE AT CAMBRIDGE, MASS., U.S.A. (*See p.* 600.)

the L.C.C. Regulations in full, including the index, as well as sixteen pages of standard notation would, I think, have come better at the end as an appendix, instead of in the middle of the book.

By far the most valuable part is Part III (Monolithic Design), which is squeezed into twenty-two pages, and a little more of this and a little less standard notation would probably have been an improvement. After all, standard notation, important as it is, should be a useful servant and not too importunate in its service.

Mr. Etchells has written a valuable foreword in which the standard notation is explained, and has assisted the author with suggestions and criticisms which have no doubt, as the author says, been of great value. Altogether the work is one which can be thoroughly recommended.

O. F.

Reinforced Concrete Design. Vol.II. Practice. By Oscar Faber, D.Sc., A.M.Inst.C.E.

London: Edward Arnold. 246 pp. + xi. Price 18*s*. net.

This book will be welcomed by many designers of reinforced concrete as one which fills a need often felt—but seldom expressed—for a practical guide which would enable them to eliminate a large amount of tedious calculation in the course of their work. The author expresses the position very well when he states that few designers have the time and ability to apply complicated formulæ for the determination of bending moments in beams and columns, and, while calculating resistance to known straining actions with great accuracy, the estimation of the moments and straining actions which have to be resisted are often inaccurate and the calculations become misleading and unsatisfactory. The aim of the author has been to secure greater accuracy in the determination of correct moments in beams and columns combined with an important saving of time in everyday practice, and this aim is one which is bound to appeal to all designers. The book is divided into three parts, the first of which deals with the accurate determination of bending moments in continuous beams where the stiffness of columns is neglected. The text is presented in simple language; the reader is taken by easy stages which will enable him readily to understand the methods to be followed, and moment curves are given for all practical cases of loading or number of spans from which the positive and negative moments can be taken at any point in the span. Part II is devoted to the consideration of moments in columns. This is a very important section of the book, because it deals in a practical manner with a subject which is frequently, and in fact usually, neglected by authors and designers, although such neglect can never be justified. The text covers both outside and interior columns, and sufficient examples of calculations are given to show the application of the formulæ presented. The third section of the volume deals with standard columns and beams, and the tables given will certainly prove a boon to the designer, as the saving in time when making calculations will be considerable while accuracy will be assured.

Chapters on the live load allowance for rolling loads and shear resistance of reinforced beams are also given. Various other important matters are dealt with in three appendices, which occupy about seventy pages.

The book can be strongly recommended as an excellent addition to the literature on reinforced concrete design, and it deals with a difficult subject in a new, helpful, and simple manner while making for that prime necessity—accuracy.

A. L.

THE PREPARATION OF CONCRETE AGGREGATES.

At a meeting of the Concrete Institute held in London on April 27, Mr. E. F. Sargeant, A.M.Inst.C.E., M.Inst.M.E., read a paper entitled "The Preparation of Concrete Aggregates," illustrated with a number of lantern diagrams and views showing typical installations for dealing with aggregates. Mr. E. Fiander Etchells (President) occupied the chair.

In his address, the lecturer said aggregate-producing plant could be divided into two broad types, namely, those in which the material was rock and those in which the material was gravel; the former had large and powerful crushers through which the material passed on its way to the screens; the latter had the material delivered direct into the screens in which it was washed and separated, the rejects or oversizes being led into the crushing plant, if they occurred in large enough quantities to justify that expense.

In designing the crushing unit a size of crusher must be chosen which would deal with the rock as brought from the quarries. Usually rock which was hard enough for concrete had to be loosened in the quarries by blasting, the larger lumps broken up by smaller shots, and the débris picked up by large grabs and loaded into wagons to go to the crusher plant. He was inclined to think the American plan of using a breaker ball attached to the crane for breaking up the larger lumps might be successfully introduced into English quarries, as the cost of blasting and reducing the lumps to a size suitable for the jaw crushers was about 1*s.* 8*d.* per ton for hard rock limestone. The product from the jaw crushers could then be taken to a smaller set of jaw crushers and passed through rolls; the diameter of those rolls depended upon the size of the material delivered by the crushers, big material being apt to fly out of smooth rolls. To overcome that the rolls were sometimes toothed or fluted, which gave them a better grip of the material. From those rolls the material was elevated by bucket elevators to overhead screens, from whence the product was taken to various storage bins whence it could be run off by appropriate chutes to wagons for distribution. Even in rock crushing and screening plants, however, too little attention seemed to be paid to the capacity of the various bins; they were usually too small to take any but a few hours' work of the plant, and when they were full the stuff either had to be wheeled away and dumped or the plant had to be stopped. The cost of a concrete storage bin for stone was only about £2 15*s.* to £3 10*s.* per cu. yd. of storage capacity, so that it paid to install large bins, as the cost of dumping and reclaiming crushed stone was fairly high unless steam grabs were employed. He had constructed concrete storage bins for grain in the bulk at 9*s.* per cu. yd. of storage capacity, but that price could not be approached for the smaller bins required for stone, and did not include foundations or roof.

GRAVEL SCREENS.

The amount of water required for washing gravel was quite considerable; an ample supply should always be arranged for, as the more copious the water supply the better the results. The pumps for a typical plant were of a capacity of 100 gals. per minute, and the average capacity of the plant was 20 tons per hour; the water supply in this case proved to be quite adequate, which would give 300 gals. per hour per ton of material, or, say, 450 gals. per hour per cu. yd. of aggregate. The aggregate in this case was river gravel, and in some cases it was fairly clean and in others mixed with a good deal of clay and river silt. In an American plant which came under his notice the pump capacity was 450 gals. per hour per ton of material, or, say, 670 gals. per hour per cu. yd. of aggregate.

The arrangement of the screening unit for a gravel plant required considerable care and thought if labour costs had to be kept low. The elementary screen was the ordinary builders' screen. The results obtained were very inferior and very costly. If the amount of sand in the raw material was small a great deal of labour was incurred in repeatedly throwing the coarse stuff at the screen; if on the contrary the percentage of large pieces was small the cost per cubic yard of screening was reduced because the majority of the stuff would pass the screen at once. The next development of this screen was the ordinary grizzly, which formed a part of many mechanical screening appliances;

if the material were fed on to the grizzly with a plentiful supply of water quite good results could be obtained.

In the ordinary type of fixed bar screen there was usually a sheet-iron chute below the screen into which the water and material passing through the screen were received, and which delivered them on to a second screen, which removed another grade, and so on ; by arranging the bars so as to pick out the coarsest material first and by introducing a plentiful supply of water over each screen one got what was most desirable, namely, that the fine material got the most washing. The defects of the fixed bar gravity screen were due to the fact that the material usually acquired too great a velocity in sliding down the screen, so that the small sizes did not pass through. Any attempt to check the velocity by cross-bars was useless, as it caused the pebbles to jump ; if the inclination were so gentle that the material passed down at a very slow rate it would pack and stick, although a plentiful supply of water minimised that difficulty. Hence those screens, while being very useful for picking out over-sizes from a quantity of granular material, were not very useful in grading the material itself, unless it consisted of mixtures of material of uniform size, such as, say, sand $\frac{1}{16}$ grains, pea gravel $\frac{5}{16}$ grains, and stone, say, $\frac{3}{4}$ grain ; piano-wire screens set $\frac{1}{4}$ in. and $\frac{3}{8}$ apart would grade that material fairly efficiently. To remedy that defect fixed bar screens were sometimes placed at a fairly flat slope and jigged or vibrated ; the slope must be sufficiently flat to prevent the material sliding down when the machines were at rest and steep enough for the material to have a uniform velocity of about 1 ft. per second when the screens were jigged or dithered.

The most commonly-used type of screen was undoubtedly the revolving cylindrical screen, which consisted of a metal cylinder perforated with appropriate-sized holes and revolving at a fairly slow rate about its axis, which was inclined at a slight angle to the horizontal. The screen might be perforated with holes of one size from beginning to end, or it might be divided so as to sort the material into various sizes, the first portion being pierced with fine holes, the next with coarser, and so on. The holes should in all cases be slightly larger than the intended size of the material, to allow for irregularities. The fine material was eliminated first, and so on, in ascending degrees of coarseness ; this was a drawback where the material had to be washed, because the fine material needed most washing, but in this arrangement it was carried through at once with the water, and so did not get thoroughly washed. A better arrangement, therefore, was the American plan of using conical screens assembled one after the other at a little distance apart, on a long shaft, which was set at an angle of about 30 deg. to the horizontal ; the wider end of each screen was uppermost, and the first screen had the largest holes, and passed, therefore, all the material except the over-size, which fell out at the lower end of the screen. The stuff which passed through the screen, mixed with washing water, was received in a steel trough, down which it slid and entered the larger end of the screen next below ; that was perforated with holes of the next size smaller, and the material was usually subjected to a further washing. A third screen might follow the second, and so on, according to the number of sizes of material it was intended to produce. That type of screen gave the most efficient washing possible, and was undoubtedly superior in this respect to the ordinary cylindrical screen.

Reverting to the latter, however, it was by no means necessary to have one long screen, as the cylinders with the various size perforations could be placed one inside the other by making them of different diameters. In that case the smallest screen had the biggest holes, and it was also made slightly longer than the next size, and so on, in order to allow of the collection of the rejects from each screen in suitable chutes. Screens of that kind were not usually used in gravel preparing, and they had the drawback that the discharge of each kind of material occurred about the same spot, thus making the distribution into the various bins a matter of difficulty ; in fact, a long cylindrical screen not only screened the material, but also acted as a distributor to carry it over considerable distances and to deposit in the respective bins, so that it was sometimes desirable to choose a screen of comparatively small diameter and considerable length in order to fill the respective bins. In a cylindrical screen the fine material was deposited near the inlet end, and the coarser material farther away until the rejects were delivered at the extreme far end. As the rejects commonly had to be crushed and elevated again to the screen delivery at the far end became a drawback. To overcome that an internal rejecting screen had been brought out, which consisted of a screen of fairly large diameter, at the receiving end of which was an internal cone, tapering inwards from the mouth of the screen and forming in itself a conical screen with perforations sufficiently big to allow all the materials to pass except the oversizes, which slid down to the mouth of the screen and were taken to the crusher. The body of the screen could be arranged in the ordinary way commencing with small holes and going on with larger ones. Screens arranged in that way must be of large diameter in order to get sufficient surface in the internal cone properly to screen out the large pieces without rejecting any of the desired size. The material, too, must be delivered at the far end of the internal cone, and if it were at all sticky it was sometimes difficult to get the chutes at a flat enough slope to do that, and at the same time to allow the material to move by gravity down the chutes. With fairly clean gravel, however, that screen was extremely useful.

Sometimes screens were carried on central shafts and sometimes on external rollers; the latter arrangement seemed preferable, and in all cases the receiving end could not have spokes, or the chute would be unable to enter. When the screen was supported on exterior rollers it was usually revolved by spur or bevel gearing, which should be very carefully arranged so as to keep it as far away as possible from the fine grit which otherwise caused rapid wear. The same attention must be bestowed upon the support at the receiving end which commonly wore rapidly from that cause.

CRUSHERS.

The next part of importance in an aggregate-preparing plant was the crushing unit. There were five types of machines ordinarily used for coarse crushing —the jaw crusher, or breaker, the gyratory crusher, the disc crusher, the roll crusher, and the edge runner. Material reduced by the above crushers could be further reduced in ball and tube mills, as for cement and paint, or by impact crushers, as for flour, chemicals, etc., but the concrete engineer never had to concern himself with the latter types.

The movable jaw plates of the jaw crusher were made either of hard chilled cast iron or manganese steel, and could be either fluted or plain. The wear and tear on the jaws was very high when dealing with river gravels, and the manganese steel plates undoubtedly lasted much longer than the cast iron. There was, however, not much advantage in their use owing to their greater cost, although the delays incurred by the more frequent renewals of the cast-iron jaws added appreciably to the cost of the latter. To get the maximum work out of a crusher the feed should be very regular at about the maximum capacity which the crusher could deal with. The delivery from the bottom of the crusher should be arranged so that by no possibility could the crusher choke up, or serious damage would be done. If the material were led away by a chute the crusher should deliver on to the chute in such a way that should the chute choke up at the lower end the crusher could overflow at the top end without choking up; this was a most important precaution and very often neglected. A jaw crusher should never be expected to give a large quantity of fine material. It would always produce a certain quantity of fine material, and the smaller the crusher the bigger was that quantity. But to produce fine material, say, ⅜ in. stuff, in large quantity recourse must be had to crushing rolls; in fact the jaw crusher was really a breaker to break up large masses of rock or stone. In mounting jaw breakers on elevated bins, etc., ample means should be taken to provide against vibration; the speed of crushers varied from 250 for small crushers to 160 for large crushers, and owing to the arrangement of the toggles the jaws usually made two swings per revolution. The jaws were fairly heavy and their momentum had to be taken down to the ground by suitable means; it was therefore advisable to mount them on the ground wherever possible.

The gyratory crusher consisted of a vertical cylindrical casting, at the top end of which was secured a truncated cone with its wide end uppermost; inside that cone hung a second cone with its wide end downwards; the second cone formed the continuation of a hollow shaft which went to the bottom of the machine, the shaft being continued above the cone, and held in a spherical bearing carried by a bridge across the mouth of the machine. At the bottom of the machine was a mitre wheel whose elongated projecting boss ran inside a suitable bearing. The boss received the lower end of the shaft which carried the inner cone in a hole which was bored rather out of the centre of the boss ; thus, when the mitre wheel revolved the shaft was carried round like a conical pendulum, the apex being at the top of the crusher. By that means the small inverted cone swung round inside the larger cone in a conical path, and thus gave a crushing action to any material introduced between the two cones. Neither of the cones revolved, however, and the crushing action was very clean without undue abrasion. The cones were usually made of manganese steel and were comparatively thin.

The disc or plate crusher was very similar to the gyratory crusher in principle, but very different in construction. In these the crushing was done between two saucer-shaped discs of manganese steel, which ran on a horizontal axis ; the outer one was perforated for the introduction of the material. They were placed with their cavities together and their edges nearly touching, thus forming a crushing chamber. The axes on which they revolved were not in line nor parallel, but were at a slight angle, one saucer in fact being carried on a shaft the far end of which was carried round in a circular path, so that that shaft too formed a conical pendulum, the axis of the cone being horizontal ; that saucer worked in a hollow cup which formed a backing to resist the crushing strains, and the circular path of the outer end of its shaft would cause the lip of the saucer to approach the other saucer with a kind of rolling motion. The second saucer was revolved by a belt pulley at speeds varying from 100 to 200 revolutions per minute, according to the size of the crusher, while the pendulum shaft was driven at twice that speed. When material was introduced between the two saucers both speedily assumed the same rate of revolution, and the material was crushed by the rolling motion of the inner saucer, being flung outward by centrifugal force. Those crushers were particularly suitable for dealing with hard pebble, which they would readily reduce to pass a $\frac{3}{4}$ ring, but some considered that their output was too low ; the speaker very much doubted, however, if they could be beaten by any other crusher for their particular class of work.

The above forms of crushers or breakers would not produce the bulk of the large aggregate required for concrete, except, perhaps, the disc crusher. After leaving the crushers, therefore, it was usually necessary to take the stone through crushing rolls. Those were very simple in principle, but called for much care and skill in design. Essentially they consisted of two metal cylinders revolving on parallel axes placed in the same horizontal plane. The circumference of the cylinders did not touch each other, but a gap was left between them of width according to the size of the material desired.

The feeds through the rolls should be carefully regulated. The maximum capacity of the rolls was, of course, the area of the opening between them multiplied by the circumferential speed, and it would be very interesting to know the average amount of voids in that volume for crushing rolls as ordinarily arranged. For instance, a pair of 18-in. roll crushers with their rims set $\frac{3}{4}$ in. apart would have an opening between them of about $\frac{1}{12}$th sq. ft. area ; at 60 revs. per minute that would give a crushing volume of 60 by 18 in. by 3.14 by 18 in. by $\frac{3}{4}$ in. =24 cu. ft. (nearly) of crushing space per minute. If that could be completely filled with stone the crushers would give an output of about 100 tons of crushed stone per hour, whereas the working output would probably not exceed 6 tons per hour. In order to obtain the maximum output through crusher rolls for flint gravel he constructed a small hopper over the rolls, the sides of which were cut to fit the curves of the rolls exactly, the curved surfaces of the rolls themselves forming the bottom ; the hopper was kept full of clean $\frac{3}{4}$ in. pebble, and under that arrangement about 8 tons per hour were passed through a pair of 12 by 6 rolls running at 60 revs. per minute. The product was crushed from $\frac{5}{16}$ down to very fine sand. That would give a maximum crushing capacity of about 16 tons per hour, as against the 8 tons actually obtained. He believed roll crushers arranged in that manner might prove very useful in the preparation of sand from gravels, but the rolls had to be of very robust design.

In all the foregoing types of crushers it was desirable not to attempt to reduce the material too greatly at a single crushing; if the material were very large and it had to be greatly reduced the operation should be done in two, three, or more stages, reducing at each stage to, say, ⅙th or ⅕th.

For producing sand from sandstone, or in crushing clinker, the edge runner or mortar mill was the most suitable form of crusher.

MECHANICAL FEEDERS.

A simple form of mechanical feeder took the form of a circular table revolving on a vertical axis. The material was delivered on to the table from a spout placed directly over, and at some distance above, the centre, where it formed a cone, the sides of which had a certain definite slope, and the cone revolved with the table. A vertical cutter was adjusted so as to cut into the cone, and the material outside the cutter was thereby forced off the table into the hopper below. By adjusting the cutter a greater or less speed was obtained. These mechanical feeds could be used for gravel or soft material like gypsum. For hard material, such as lump limestone, the tray feed was better. That consisted of a flat reciprocating tray with sides placed below the hopper mouth. The hopper mouth was rectangular on plan, two of the sides and the back being brought down to the level of the tray, while the fourth side or mouth terminated at a sufficient distance above the tray to let the largest lumps pass through. As the tray was pushed forward it carried the material with it and fresh material descended. The tray then moved back and slid under the material. At a fresh forward stroke more material descended, and so on, until the material finally fell over the front edge of the tray, giving an intermittent delivery.

A form of mechanical feed very common in America was an articulated metal belt carried on two pulleys, something like a caterpillar tractor, which was placed directly under the hopper mouth, and gave a continuous feed.

For small stone of uniform size and sand the speaker frequently employed a long hinged chute on to which the bin opening delivered. By making the slope of the chute steeper than the natural angle of the material the latter flowed down at a certain speed varying with the slope, and by raising the chute the delivery stopped instantly. The apparatus was very easy to construct, and gave very good results with washed gravel of uniform size; with sand, however, the natural angle of which varied so much with its moisture, the results were not so satisfactory.

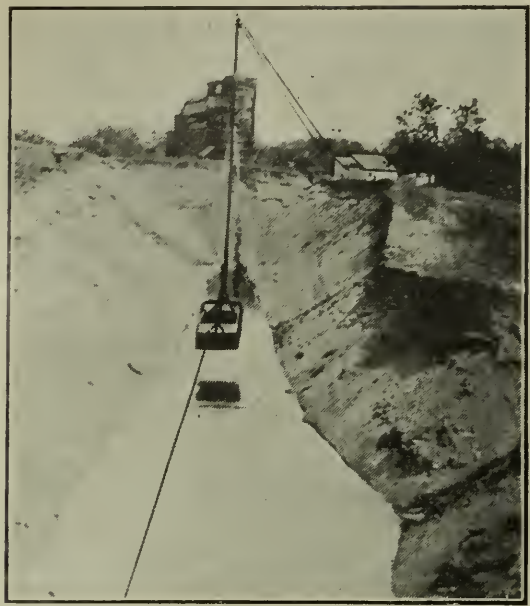
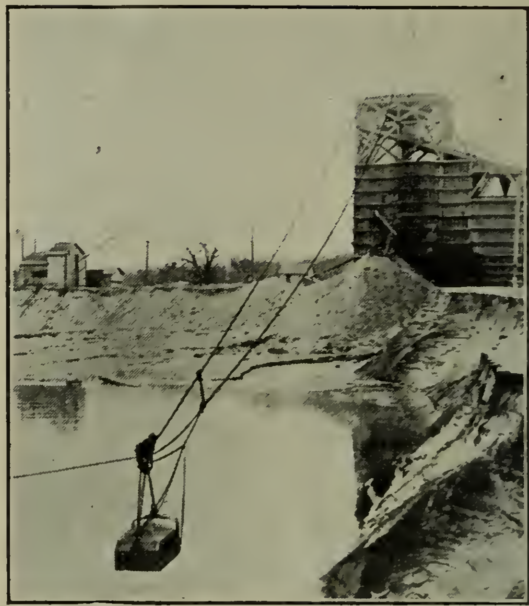
WATER SEPARATORS.

In America a very common form of water separator was a truncated cone of sheet metal, the lower end of which was closed by a disc which was held to a fixed beam, the cone itself being counterpoised. Sand and water flowed in at the top and the water overflowed, carrying with it the mud; when it was full of sand the cone dropped for some distance and allowed the sand to flow out past the valve.

Another and very ingenious form of water separator was the subject of a patent. It consisted of a wide angled cone made of sheet metal revolving on a horizontal axis; a number of troughs were fixed to the outside of the cone, running from the base to the apex. As the cone revolved that particular trough which was on the horizontal diameter of the cone was perfectly level from end to end, but in a quarter of a revolution the trough would have a fall towards the apex of the cone depending on the taper of the cone. If water and sand were introduced into the trough when it was horizontal the water would be run off as the trough approached the vertical diameter of the cone, leaving the sand behind; in another quarter of a revolution the same trough would be in a horizontal plane once more, but would be inverted, allowing the sand to drop out.

EXCAVATORS.

In choosing the size of grab for any particular output regard must be had to the time occupied in adjusting the grab over the material and over the hopper. The former operation when grabbing from a barge or railway truck was always much more lengthy than one would imagine. With single chain grabs he had found the best way of dealing with the large flints which were sometimes present in the gravel was to knock them out of the jaws with a 7-lb. hammer, although that was apt to cause severe shocks to the crane; he had never known any harm happen,

A DRAGLINE EXCAVATOR.

however, if the grabs were worked by a rope on the crane instead of a chain. With two chain grabs the grab could easily be opened to get rid of the obstacle, but even here with gravels containing a fair proportion of large-size flints it was a nuisance which had to be reckoned with. Grabs for digging hard packed material should be of the variety in which the cylindrical shell was placed by a series of massive steel bars which dug into the material, whereas for loose material plate grabs were amply sufficient.

The dragline was particularly suitable for digging gravel for concrete purposes. The buckets were made of various capacities from $\frac{1}{4}$ yd. to 2 yds. and the span might be anything up to 900 ft. The height of the mast should be $\frac{1}{7}$th of the span, and masts were usually in steel for the heavier equipment, although for smaller spans and equipment a mast of trussed timber would suffice. The masts usually required six guy ropes, preferably at an angle of 45 deg. to the ground, and the anchorages needed very careful attention. Where the deposits were shallow it was preferable to anchor the outward end of the track cable to a bridle cable, the anchorages of which were perhaps 120 ft. apart; the track cable could be made to travel along the bridle cable by a pulley block arrangement, so that the track cable could operate over a segment of a circle having a chord of 120 ft., by which an enormous quantity could be dug without fresh anchorages.

DISCUSSION.

In the ensuing discussion, **Professor F. C. Lea** said it was very necessary when preparing gravels, especially pit gravels, that a very large quantity of water should be used in order that they might be thoroughly washed. Good concrete could not be produced unless the aggregates were quite clean.

Mr. A. H. Barnes moved a hearty vote of thanks to the lecturer.

Mr. H. K. G. Bamber seconded the motion, and said one of the principal bug-bears of the cement manufacturer was the complaints received from time to time as to the failure of concrete; nine times out of ten, upon investigation, these failures turned out to be due to dirty concrete aggregate being used.

Mr. Paine said it would be interesting to hear if the lecturer had had any experience of breakers where centrifugal methods with bolts or weights flung out were used for crushing flints or clinker.

Mr. White said his firm, in connection with crushers for coal, often found colliers' drills, etc., getting in the rolls and sometimes breaking the gears. To remedy this they had put shear bolts in a flange on the shaft, so that if foreign matter got in the bolts sheared, and the crusher rolls were saved.

The **Lecturer** said it was common to put cast-iron lugs on the rolls when crushing rock, so that the lugs broke off when steel got between them.

Mr. S. Bylander said he had had considerable trouble as to what was meant by $\frac{1}{2}$-in. gravel, and what was meant by $\frac{3}{4}$-in. gravel. He had adopted the custom of specifying that $\frac{3}{4}$-in. crushed gravel was material which had passed through a screen with 1-in. diameter holes.

The Chairman said certain engineers specified that $\frac{3}{4}$-in. aggregate was that which would fall through a mesh $\frac{3}{4}$-in. square, measured in the clear. A piece of aggregate might be longer than it was broad; since it had to fall through the mesh and not be pushed through, if it were $1\frac{1}{2}$-in. long it would lie on the screen, but if it were less than that length it would probably over-balance and fall through. Thus, the general meaning of "$\frac{3}{4}$-in." was a piece having a diameter not exceeding $\frac{3}{4}$-in., and a length not exceeding $1\frac{1}{2}$ in.

The **Lecturer,** replying to the questions, said, as to the crushing of flints, he believed the "Hockley" crusher would do that work satisfactorily. As to the size of holes, some engineers specified that $\frac{3}{4}$-in. stuff should pass through $\frac{3}{4}$-in. holes, but if an engineer specified that, he got not $\frac{3}{4}$ in. but $\frac{5}{8}$-in. Every piece of aggregate was jagged on the edges. For $\frac{3}{4}$-in. stuff 1-in. holes would be too big; he thought $\frac{7}{8}$-in. holes would pass $\frac{3}{4}$-in. stuff.

The vote of thanks was passed with acclamation.

THE VILLENEUVE BRIDGE.

The bridge over the River Lot at Villeneuve is unique, inasmuch as it consists of two parallel arches of 300 ft. span built of concrete without reinforcement. The erection was begun in 1914, and the centering was removed in 1915, but no further

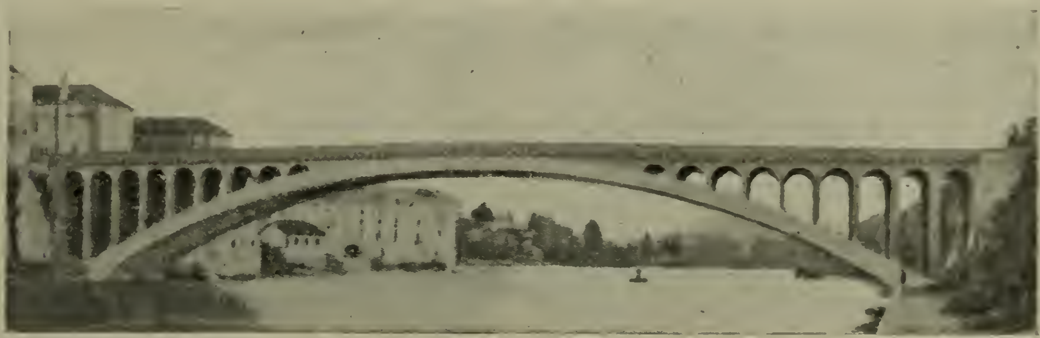


FIG. 1. THE VILLENEUVE BRIDGE.

work was done until four years later, with the result that the bridge was finished less than a year ago. The roadway of the bridge, including two footpaths, has a total width of 36 ft. The two supporting arches are 16 ft. apart. The designer claims that the avoidance of reinforcement is economical, because it enables various simplifications to be effected in cases where the superincumbent weight is not excessive.

The specifications issued with the request for tenders did not mention the composition of the concrete, but simply stated that it must have a compression strength of at least 3,360 lbs. per sq. in. after ninety days. The sand and gravel actually used were obtained from the River Lot. Only sufficient cement was added to ensure the concrete having the specified strength.

The foundations of the roadway are of reinforced concrete, and consist of a series of slightly reinforced concrete piers and a flat foundation stretching right across the

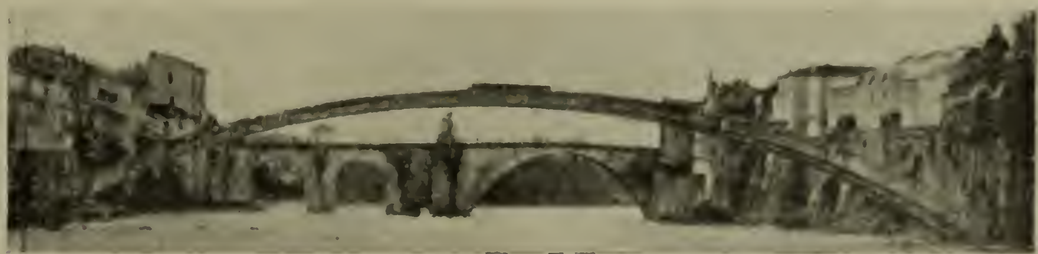


FIG. 2. VILLENEUVE BRIDGE: PARTIALLY COMPLETED.

river, this table being also reinforced. The upper part of the bridge is faced with bricks. The parapets are of reinforced brickwork.

During the years 1915–1919, when the plain concrete arches were left unsupported by any centering and without the ties formed by the superstructure, they sustained several severe storms and floods without the least harm.—*Le Genie Civil.*

CEMENT NOTES.

By Our Special Contributor.

Concrete in Sea Water.

INTEREST in the problem of the behaviour of concrete in sea water is revived by the publication of the report of the Committee of the Institution of Civil Engineers on "Deterioration of Structures in Sea-Water," summarised in the July issue of this Journal.

The behaviour of concrete in sea water has been the subject of intermittent discussion since the failure of the Aberdeen Dock in 1889, when it was at first thought that the cause of the failure was the presence of an undue proportion of magnesia in the cement. This conclusion was subsequently proved to be erroneous by the discovery that the magnesia existing in the disintegrated concrete was derived from the sea water, and the failure was ultimately attributed to the porosity of the concrete. A further alarm was raised when it was announced that the sulphate of magnesia occurring in sea water, interacting with cement, caused the formation—with considerable swelling—of calcium sulpho-aluminate, and this might be a fruitful source of disintegration of concrete immersed in sea water. It was then realised that this destructive action could only occur if the sea water found entrance to the concrete, and that a dense and impervious concrete would not be affected by this possibility. Upon the discovery of the possible effect of the interaction of sea water and cements containing alumina there arose a preference for cements containing the minimum proportion of alumina; but there seems small ground for such preference, because a cement containing 4 per cent. of alumina instead of the usual 8 per cent. could not be expected to be proof against expansion if sea water percolated the concrete. A more rational procedure was the production of cement containing no alumina, its place being taken by iron oxide, but there has been no widespread use of such cement, probably because it has been cheaper and more satisfactory in the end to produce an impermeable concrete.

In some American experiments commenced in 1909 concrete specimens partly immersed in the sea at the Navy Yard, Charlestown, have been under periodical observation, and after 11½ years no deterioration has taken place in specimens made with various cements ranging from those containing no alumina to those containing a high proportion.

The inclusion of pozzuolana or trass as one of the constituents of concrete has been advocated as a measure for resisting the action of sea water, and there is a considerable body of evidence in its favour. The mode of its action is apparently to make a denser and stronger concrete, because of the interaction of lime in the cement with active silica in the pozzuolana or trass. The use of these materials has, however, been largely confined to those countries in which they occur as natural deposits, namely, the countries of Central Europe and Italy.

To maritime nations the subject of deterioration of structures in sea water is of great importance, and it is not surprising that world-wide experiments to determine the factors which affect the stability of concrete in sea water have been undertaken. These experiments have usually taken the form of immersing specimen pieces of concrete in sea water under varying conditions and observing their condition at intervals spread over many years.

In the United States the action of sea water on concrete is being investigated by observations on the condition of structures with the object of determining the conditions required to produce durability in concrete when exposed to sea action.

In the first of the series of bulletins on the subject emphasis is laid on the importance of using the correct proportion of water with concrete, extensive disintegration of concrete walls built prior to 1901 being attributed in large measure to the use of too small an amount of water in mixing. In another instance concrete of three different consistencies had been used in one pier and there was evidence of the advantage of using a medium amount of water—that required to produce a quaking consistency. The British Admiralty recommendation of at least 2 in. covering to the reinforcement is confirmed by the American observers, and the importance of dense concrete is also emphasised.

Probably the most systematic testing investigation of the action of sea water on concrete has been undertaken by the Scandinavian Portland cement manufacturers, who commenced their work in 1896. The tests have been most severe, because on the coasts on which the test pieces have been exposed freezing and thawing of the blocks have occurred twice daily during the alternations of high and low tide with the corresponding immersion and subjection of the blocks to air temperatures well below freezing point. Some of the test blocks were of ¾ yd. bulk and formed part of a concrete groin.

The final report—after twenty years' testing—does not yet appear to have been issued, but the ten years' observations show that blocks in which the proportion of cement to sand (ignoring large aggregate) is 1 to 1 or 1 to 2 are intact, while, as might be expected, the blocks of 1 cement to 3 of ungraded sand, being porous, are unsatisfactory; many concretes of 1 cement to 3 *graded* sand are perfect. The concrete blocks in the groin were of 1 : 2 : 4 and 1 : 3 : 5⅛ mixes respectively, and the former are satisfactory after ten years, except where the sand grading is unsuitable. It is somewhat surprising to observe that some of the latter weak mixings are also intact.

Among the conclusions reached by the Scandinavian observers are the following :—

(1) The chemical action of the sea water alone is not able to destroy the mortar, as the Portland cement appears to be more or less unaltered.

(2) The destruction of the mortar and concrete is for the greatest part due to the mechanical influence of the frost.

(3) The mortar mixture of 1 : 3 is too poor for sea water in Scandinavian climates.

The disintegration of concrete under sea action which has taken place may be attributed to one or more of the following causes :—

(1) Purely mechanical action, such as attrition.
(2) Chemical action.
(3) Frost.

To resist mechanical action it is necessary to produce a hard concrete by the use of a hard aggregate and a strong cement, protecting the concrete from the force of the waves for as long as possible from the time of moulding, and in this connection the value of pre-cast blocks is obvious. Chemical action is only effective when the sea water finds entrance below the surface of the concrete and forms the crystals of calcium-sulpho aluminate which, by swelling, are a cause of disruption. Dense and impervious concrete is the remedy in this case, and the investigations with the accompanying literature on the proportioning of concrete have been so extensive during recent years that this point needs no elaboration.

From the third cause of disintegration mentioned, namely, frost, it is obvious that a non-porous concrete free from cracks has little to fear, but frost would accelerate the disruptive action commenced by other means.

From the British Admiralty report it is interesting to note that mortar joints of masonry consisting of lime mortar pointed with Roman cement have failed, and in consequence Portland cement has been adopted as a pointing material. With the possibility of obtaining a quick-setting Portland cement of guaranteed strength and soundness there seems to be no necessity to resort to Roman cement for tidal work of this description.

Cement as a Fire Extinguisher.

The juxtaposition of cement and timber is not at all uncommon, especially in builders' yards and on construction sites, so that the possibility of using cement as a fire extinguisher, recently demonstrated at Seneca, U.S.A., during a fire at a timber yard, has a practical interest. The *modus operandi* was to sprinkle dry cement on the timber which was in danger of catching fire and then to wet it with buckets of water. None of the timber so treated became ignited. On the timber already alight a thin mixture of cement and water was thrown, and this had the effect of preventing the flying of sparks and tinder, and ultimately of extinguishing the blazing timber because the cake of cement had a smothering effect and prevented combustion.

A NEW METHOD OF BUILDING CONSTRUCTION.

We have recently had the opportunity of inspecting a new system of building as applied to factories, power stations, and other large structures. The essential members of this system are reinforced concrete slabs 12 ft. by 11 ft. by 4 in. thick. The reinforcement consists of ½-in. bars forming a mesh of 13 in. by 8 in., placed 1 in. from the inner surface of the slab, the bars being tied with 16-gauge wire. The slabs are made horizontally, and the method of moulding is as follows :—A platform consisting of planks is placed on level ground or supports, and upon this the four sides of the

Fig. 2. Concrete Slab being Lowered into Position.

mould are placed. This is filled, and the reinforcement placed, in the ordinary way. On the top of this slab another platform is laid and a second slab moulded. This process is repeated until a high pile of slabs has been produced.

In the construction of the building a framework of angle-irons for the corners and H-beams for the sides is first erected. In the spaces between the members of the steel framework the slabs are fitted as shown in the accompanying sketch (*Fig.* 1), one resting on another to the top of the wall.

Each slab is three tons in weight,

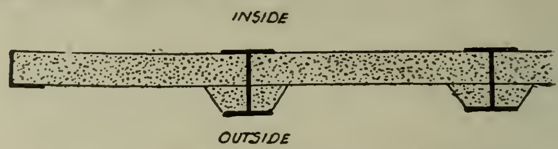


Fig 1. Showing how Slabs Fit into Steel Framework.

and has to be elevated by a crane.

A variation of this method is employed for the erection of bungalows. In this case the slabs are smaller (2 ft. by 1 ft. by 3 in. thick), and are not reinforced. The shape of the slabs is shown in *Fig.* 3. The slabs fit between H-beams with angle-irons at the corners, as in the case of the larger slabs. On the inner side each slab rests upon the one below, but on the outer side there is a space, which is afterwards filled with cement mortar.

Internally no plaster is applied to the walls, the distemper being applied direct to the concrete. It is said that a bungalow of this type can be built for £380, or approximately 1*s*. per cu. ft.

Boundary walls, retaining walls, sheet piling and other heavy engineering work can, it is claimed, be carried out with economy in time and labour. Basement walls are constructed with reinforced runners varying from 4 in. to 7½ in. for depths to 10 ft. and to 18 ft. respectively, together with steel vertical beams. Where the wall has to be kept clear of the main walls of the building the overturning effect due to earth pressure is dealt with by horizontal girders at ground level and the reaction of the basement floor. Further particulars of the system may be obtained from Mr. C. A. Trayte, architect, "Farleigh," Upton Road, Bexleyheath, Kent.

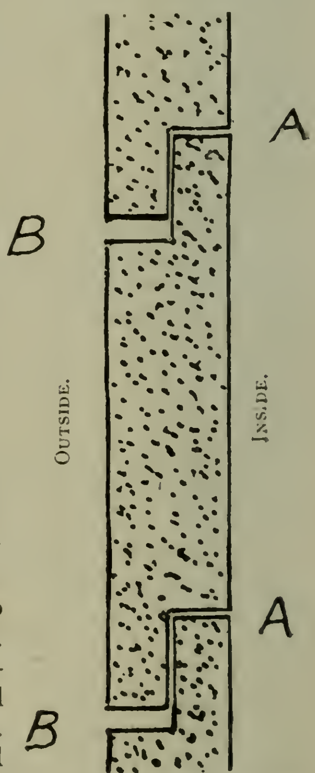


Fig. 3. Section of Walling, showing the Blocks in contact on the inside (A) and with a space on outside (B) which is afterwards filled with Mortar.

CORRESPONDENCE.

STRESSES ON HIGH TENSION AND MILD STEEL.

Sir,—With reference to the recent controversy brought about by Mr. Shelf's letter concerning the use of high-tensile steel in reinforced concrete beams, Mr. Shelf denies that the use of high-tensile bars requires an increased thickness of concrete. I think the best way to illustrate the effect of high-tensile steel as compared with mild steel in a T-beam is by means of simple diagrams.

If a line A–B represents the maximum stress in the concrete in compression at the top of a T-beam, viz., 600 lb. per sq. in., and a line C–D represents the tension per sq. in. in the steel at the bottom of the T-beam, viz., 16,000 lb. per sq. in. for mild steel, the position of the neutral axis is indicated in *Fig.* 1. This occurs where the stresses on both steel and concrete are zero.

If we now substitute high-tensile steel for mild steel the stress per sq. in. will be increased to 20,000 lb. and the line C–D will become longer. Consequently the neutral axis will be higher (*Fig.* 2), so that the area of the concrete in compression between the top of the T-beam and the neutral axis will be reduced.

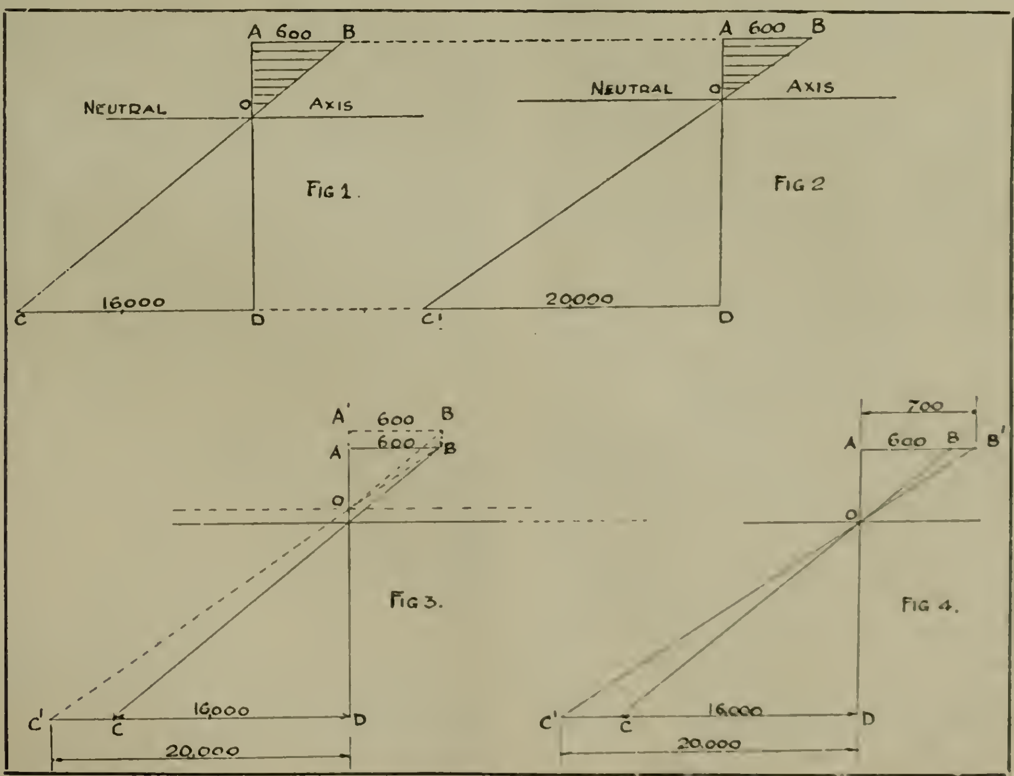
One of two things must then happen. Either we must heighten the beam to increase the sectional area of the concrete in compression (*Fig.* 3) or else we must have a richer concrete capable of, say, 700 lb. per sq. in. (*Fig.* 4), otherwise we would overstress the concrete.

The diagrams are, of course, based on the usual assumption that the deformation across the section of a beam can be indicated by a straight line.

G. C. Workman,
Managing Director.
Edmond Coignet, Limited.

London.

Sir,—Replying to Dr. Faber's letter, which appeared in your July issue, I note that he disagrees with my contention as to the safe working stress on high-tensile steel in comparison with mild steel.



See letter from Mr. G. C. Workman.

Surely the records of tests carried out by the Concrete Institute at the Manchester School of Technology, and shown at the bottom of page 553 in your August issue, support my contention.

If Dr. Faber is still unconvinced, I would suggest a further series of tests be carried out on slabs reinforced with mild steel rods and slabs reinforced with B. & T. twisted rods, but 20 per cent. less in area than the mild steel reinforcement. The tests to be carried out under the supervision of the Editor of *Concrete* in London or the Concrete Institute. If he agrees to this, I shall be pleased to make arrangements with him to have them carried out.

Arthur W. C. Shelf.

London, W.

Sir,—It is clear from Mr. Shelf's last letter (August 15) that he thinks I disagree that high-tension steel will sometimes carry a higher stress than mild steel in a concrete beam. Yet if he will refer to his previous letter (in your July issue) and my reply, he will see that what I disagreed with was his statement that the use of smaller rods at a higher stress did not raise the neutral axis, which is quite a different thing. If there were a little more "theory and mathematics in reinforced concrete" we should not fall into these little traps.

I am, of course, well acquainted with the tests Mr. Shelf mentions, which showed, as could have been foreseen, that beams under-reinforced gained in strength by the use of high-tension steel. But they did not show that the neutral axis was not raised, or that the substitution would be economical in rectangular beams (it generally is not), or that the greater elongation does not lead to greater risk of corrosion and other disadvantages which make the wisdom of the substitution very doubtful.

Oscar Faber.

London.

ROAD REINFORCEMENT.

Sir,—In your June issue Mr. Walker refers to a previous letter of mine, and states that a road in Somerset, longitudinally reinforced, cracked along the centre line. May I point out that his statement is hardly correct? The road was constructed in two halves with a longitudinal joint, and he has mistaken a joint for a crack. The joint was filled in with asphalte at a trifling cost, and the road, which has now been in use for nearly two years, has a perfect surface. The cost of this road was 5*s*. 3*d*. per square yard less than that of an adjoining length of road which was reinforced transversely as well as longitudinally, and so far as can be seen it is equally good.

The question of dealing with the longitudinal joint in roads constructed in two halves is quite a different matter from the general question of reinforcement, but Mr. Bennett, County Surveyor of Monmouthshire, has obtained a perfect joint on the main road between Brecon and Abergavenny, by continuing the reinforcement, which is longitudinal, with light transverse wires across the joint. This road, as an example of a complete concrete road, should be better known. It carries the main traffic between Brecon and Abergavenny, and as there is no railway the road traffic is very heavy. It was laid in 1919 with concrete 6 in. thick with single-layer mesh reinforcement, and has retained a perfect surface without any expense on maintenance.

Mr. Walker also refers to a difficulty of making single layer mesh with equal reinforcement both ways. As far as electrically-welded mesh is concerned there is no difficulty either from a practical or a commercial point of view. It is in fact easier to make than the mesh with main wires longitudinal, but the latter has always been used for road work because, as mentioned in my previous letter, longitudinal reinforcement is theoretically the correct thing for concrete roads. In actual practice the longitudinal method has been used on more than 1,000 British roads over a period of ten years and has given perfect results.

J. F. Butler,
Managing Director.

The British Reinforced Concrete Engineering Co. Ltd.

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—ED.

REINFORCED CONCRETE PILES.

QUESTION.—The following question was given at the October, 1921, examination for Associate Membership of the Concrete Institute:—"Make a design of a reinforced concrete pile to carry a dead load of 300 tons. It may be assumed as penetrating 20 ft. into a stiff clay soil and standing out 15 ft. Specify weight of ram and drop required for driving the pile. How long should the pile be cast before use, and what precautions should be taken in handling it?" I should like to know the procedure for designing such a pile. I have not been able to find anything in the text-books, nor a record of a pile carrying such a heavy load alone—STUDENT.

REPLY.—We agree that 300 tons on a single pile is something quite out of the ordinary, and, we should have thought, perhaps an unfortunate example. The example is complicated by the fact that if the pile were made just strong enough to carry the load it would have insufficient surface in contact with the clay to prevent settlement, under a load of 300 tons, at least with any ordinary "stiff clay." But we presume the reply required is something as follows:—Adopting a stress of 500 lb./in².,

$$\text{Area required} = \frac{300 \times 2240}{500} = \underline{1344} \text{ Sq. in.}$$

	Sq. in.
A pile 33 × 33 gives	1089
12 $1\frac{1}{2}$ in. rods give equivalent area of 12 × 1·76 × 14	295
	1384

This pile would weigh

$$\frac{35 \times 2\frac{3}{4}^2 \times 150}{2240} = 17{\cdot}7 \text{ tons}$$

so clearly a very heavy ram would be required, probably nothing less than 10 tons being desirable. We know of no pile frames which would carry this, but then the example, to our mind, is a little fantastic. The necessary drop must be obtained from one of the pile-driving formulæ—all of which, however, give quite different results and do not readily lend themselves to strictly scientific treatment—another reason why we consider the question an unfortunate one for an examination.

As regards the last part of the question, presumably the examiners require the age to be about six weeks (depending on temperature and cement content), and the precautions referred to are perhaps the necessity for using a helmet and of supporting it in slinging, so as not to produce excessive bending stresses, though there is no indication of what special precautions are referred to.

In our view, the question would have been a more fortunate example had it read 30 instead of 300 tons, and is unfortunately chosen in many other respects.

CONCRETE BEAMS.

QUESTION.—A rectangular beam of concrete 12 in. wide and $13\frac{1}{2}$ in. deep, reinforced by four bars of steel $\frac{3}{4}$ in. diameter placed 12 in. below the upper surface—If the maximum compressive stress in the concrete is to be 150 lb. per sq. in., find the position of the neutral axis and the moment of resistance, and also the tensile stress of the steel. Take $\frac{Ec}{Es} = \frac{1}{10}$—F.C.

REPLY.—Percentage of steel

$$p = \frac{4 \times {\cdot}44}{12 \times 12} = 1{\cdot}23\%$$

whence $n \left(\text{with } \frac{Ec}{Es} = \frac{1}{10}\right)$
$= \cdot 386.$

[From formula, or see Faber & Bowie, "Reinforced Concrete Design," Vol. I, p. 28.]

Moment of resistance with $c = 150$ lb./in².

$$= \frac{150}{2} \times (12'' \times 12'' \times \cdot 386) \times 12'' \times \left(1 - \frac{\cdot 386}{3}\right) = 43{,}800 \text{ in. lb. (approx.)}.$$

The tensile stress is

$$\frac{\frac{150}{2} \times (12'' \times 12'' \times \cdot 386)}{1 \cdot 76}$$
$$= 2{,}360 \text{ lb. in}^2.$$

CONCRETE AND THE REPAIR OF ANCIENT BUILDINGS

QUESTION.—Would the expansion of a ferro-concrete beam built longitudinally into an old stone wall—to strengthen it—be the same, the original wall being built in lime mortar ?—P. M.

ANSWER.—The expansion and contraction of a concrete beam built longitudinally into a stone wall would be practically identical with the rest of the wall, and would, under ordinary circumstances, give no trouble.

CONCRETE AGGREGATES—*continued.*

Norfolk—(Fakenham).

(1) *General description :* Stone pits.
(2) *Source and locality of same :* Holt, Hempton, Fakenham.
(3) *How obtained :* Screenings from stone.
(4) *From whom obtained ?* N.C.C., and Mr. Gayford, Raynham Estate Office.
(6) *Present maximum output per day (stated in cubic yards) :* 10 to 12.
(7) *Transport facilities :* Holt by rail and road ; Hempton by road.
(8) *Is there any provision at or near source for washing or crushing ?* No.
(9) *Price per cubic yard, and where delivered :* At pit, 3*s*. 9*d*.
(10) *Is composition uniform ?* Yes.
(11) *Detailed description :—*
  (*a*) *Kind of stone or coarse material :* Flints.
  (*c*) *Relative proportions of coarse and fine material :* 75 per cent. to 25 per cent.
  (*d*) *Shape of particles (rounded, angular, flat, etc.) :* Rounded, angular, flat.
  (*e*) *Size of particles ; approximate percentage that needs crushing to pass ¾ in. screen :* 75 per cent.
  (*f*) *Impurities present (as clay, sulphur, coal, organic matter) :* Clay.
(12) *Is sample sent with this sheet ?* No.

Norfolk—(Gt. Massingham).

(1) *General description :* Gravel flints.
(2) *Source and locality of same :* Caldwell's Pit, Gt. Massingham.
(3) *How obtained :* Manual labour.
(4) *From whom obtained ?* Estate of Earl of Leicester.
(5) *Is quantity limited ? If so, how ?* Unknown ; depth of face, 10 ft.
(6) *Present maximum output per day (stated in cubic yards) :* 6 cu. yds.
(7) *Transport facilities :* Road haulage.
(8) *Is there any provision at or near source for washing or crushing ?* No.
(9) *Price per cubic yard, and where delivered :* 4*s*. 9*d*. cu. yd. at pit.
(10) *Is composition uniform ?* Yes.

(11) *Detailed description :—*
 (a) *Kind of stone or coarse material :* Mainly blue flints.
 (b) *Kind of sand or fine material :* Very small percentage of building sand.
 (c) *Relative proportions of coarse and fine material :* About equal.
 (d) *Shape of particles (rounded, angular, flat, etc.) :* Rounded.
 (e) *Sizes of particles ; approximate percentage that needs crushing to pass* ¾ in. *screen :* Approximately 85 per cent.
 (f) *Impurities present (as clay, sulphur, coal, organic matter) :* 15 per cent. loam (approx.).
(12) *Is sample sent with this sheet :* No.

Norfolk—(Hoe).

(1) *General description :* Red gravel ; deep seam ; extra good stone.
(2) *Source and locality of same :* Hoe Gravel Pit, Hoe.
(3) *How obtained :* Manual labour.
(4) *From whom obtained ?* F. Hornor & Son, Estate Agents, Norwich.
(5) *Is available quantity limited ? If so, how ?* Unlimited.
(6) *Present maximum output per day (stated in cubic yards) :* No record.
(7) *Transport facilities :* Engine and team labour.
(8) *Is there any provision at or near source for washing or crushing ?* No.
(9) *Price per cubic yard, and where delivered :* 1s. royalty per cu. yd. in pit.
(10) *Is composition uniform ?* Yes.
(11) *Detailed description :—*
 (a) *Kind of stone or coarse material :* One-fourth ¾ in., one-fourth 2 in., one-fourth 3 in., one-fourth 4 in. stones.
 (b) *Kind of sand or fine material :* Good path gravel ; no sand ; can make shingle.
 (c) *Relative proportions of coarse and fine material :* See (a) and (b).
 (d) *Shape of particles (rounded, angular, flat, etc.) :* Rounded and angular.
 (e) *Size of particles ; approximate percentage, that needs crushing to pass ¾ in. screen :* See (a).
 (f) *Impurities present (as clay, sulphur, coal, organic matter) :* None.
(12) *Is sample sent with this sheet :* No.

Norfolk—(Litcham).

(1) *General description :* Gravel flints.
(2) *Source and locality of same :* Starling's Pit, Litcham.
(3) *How obtained :* Manual labour.
(4) *From whom obtained ?* Mr. C. C. Griffin, Wellingham, Fakenham.
(5) *Is available quantity limited ? If so, how ?* Area of bed unknown ; depth of face, 15 in.
(6) *Present maximum output per day (stated in cubic yards) :* 6 cu. yds.
(7) *Transport facilities :* Road haulage.
(8) *Is there any provision at or near source for washing or crushing ?* No.
(9) *Price per cubic yard, and where delivered :* 4s. 9d. per yd. at pit.
(10) *Is composition uniform ?* Yes.
(11) *Detailed description :—*
 (a) *Kind of stone or coarse material :* Blue and grey flint.
 (b) *Kind of sand or fine material :* Large percentage of building sand.
 (c) *Relative proportions of coarse and fine material :* 5 of fine to 7 of coarse (approx.).
 (d) *Shape of particles (rounded, angular, flat, etc.) :* Rounded.
 (e) *Size of particles ; approximate percentage that needs crushing to pass ¾ in. screen :* 80 per cent. (approx.).
 (f) *Impurities present (as clay, sulphur, coal, organic matter) :* Small percentage of loam.
(12) *Is sample sent with this sheet ?* No.

REINFORCED CONCRETE ROADS AT MIDDLESBROUGH.

Of the schemes approved by the Middlesbrough Corporation for works of improvement to roads, and which have been carried out by labour which has been thrown into the market by reason of the unemployment and distress prevailing, twenty-two roads in the County Borough have been reconstructed in reinforced concrete. The old macadam roadways have been done away with, the old material excavated to

Concrete Road at Middlesbrough.

the required depths, and reinforced concrete carriageways carried out. The reinforcement on a number of these roads is B.R.C. No. 9 Fabric, which is so arranged that it provides against tensile contraction stress throughout the full section of the

Concrete Road at Middlesbrough.

transverse slope of the *in situ* concrete forming the transverse slab across the road. Mr. S. E. Burgess, M.Inst.C.E., Borough Engineer and Surveyor, informs us that no cracking either transversely or longitudinally is experienced; the roads are giving every satisfaction, and the stability of the work is sound in every particular. Walker-Weston double layer reinforcement is also being used on some of the roads at Middlesbrough.

LEAVES FROM THE DIARY OF A PRACTICAL CONCRETER.

(Continued.)

CEMENT TESTS.

HAVING spoken about a little knowledge being dangerous in testing, I would like to refer to several instances which have come under my notice during many years of experience. One thing I do think is that it should be part of the training in our technical schools for building construction that all the students should be made to do a series of cement tests in order that they may be better fitted for the positions of clerks of works. As it is, cements are often condemned unjustly since the testers overlook many of the minor details in the British Standard Specification, and in fact, in the eyes of an experienced person, do some very absurd things. For instance, I visited a job where an inch of sand and cement finish was placed on some very old concrete and which cracked badly, and the clerk of works informed me that the cement had expanded, causing these cracks. I assured him, however, that he was on the wrong tack and the cracks were caused by contraction, not expansion, owing to the dry state of the underneath concrete which had absorbed the moisture from the sand and cement topping. As he was very interested in testing and apparently had done a considerable amount, we each made a set of briquettes with the condemned cement, he using $23\frac{1}{2}$ per cent. of water, and I using $18\frac{1}{2}$ per cent. The result was that the briquettes containing $18\frac{1}{2}$ per cent. water broke at 20 per cent. higher tensile strain than the others, at 7 days, owing to the small quantity of water used and with labour in its stead. Other examples could be given showing the important bearing consistency, or in other words water content, has upon strength.

There is also another very vital question in cement testing, that is, the machine which is used for tensile tests.

Some thirty years ago in a Midland town, my firm was condemned on a water machine which took five minutes to break a block at 400 lb., this being obviously wrong, and the manufacturers of the machine took it away and adjusted it, after which we got no further condemnation.

Many clerks of works still believe in the old bottle test, which is very primitive, and was never a fair test unless to tell the amount of underburnt clinker in the cement. The cracking of the bottle could be accounted for in many ways beyond expansion in the cement. A better way to test for soundness, which would also give a rough test for the initial and final time sets, is to make up a pat of cement about 3 in. long and 3 in. wide, and place it on a piece of glass or sheet iron. The pat should be tapered at the edges from $\frac{3}{4}$ in. in the centre, using, say, about 20 per cent. to 22 per cent. of water. This should be kept in a regular moist atmosphere of, say, 58–64° F., and away from any draught. If the fine edge cracks one will naturally ask questions.

I was called on to a job in Yorkshire some time ago and the clerk of works showed me some such pats he had made which were cracked very badly, and upon asking him how he had treated them after making, he informed me that he had immediately placed them under water before he had even obtained the initial set, therefore giving them a cold water plunge test, which of course, as a rule, slow setting cements will not stand. I pointed out to him that he was doing something beyond the demands of the B.S.S., but he informed me that this was their own test and I then told him that he should have ordered cement accordingly, and firms would then supply him with a cement with which that test could be carried out.

About ten years ago I was invited to give a professional opinion on about 1,000 cubic yards of concrete which had been used for stanchion bases, and where a cement was blamed for the non-setting and the weak concrete. During a heavy gale many of the stanchions had been completely ripped up from the bases, which were on the grillage system. In the specification a clause was added to the effect that if any material found on the job was suitable for concrete it could be used. The engineer and contractor thought, when the digging commenced, they had come across a " gold mine " of gravel and sand, but they were disillusioned when, at first sight, I condemned the whole of it and explained that this material was at the root of their whole trouble. I afterwards made tests of the cement on the job and found it perfectly satisfactory, although it had been stored some considerable time in an inferior shed in the depth of winter. The engineer asked what steps he should take to stay any further trouble and what he could do with his " gold mine." My summing up was to condemn the whole of the work done, and it must be taken out (which, however, did not take long to do) as the work would never be satisfactory because the gravel and sand was dirty, and, worse, it contained a large amount of peat and other carbon matter.

This brings me on to another job where some cement plastering work had been done, and it was cracking badly. My advice to the contractor on this occasion was to get it hacked off the brickwork at once, otherwise, being at the top of the building, it would get the frost in the cracks and they would have pieces dropping on peoples' heads. The contractor wanted to know the cause of the trouble, and I at once told him that lime had been used in the cement plaster. The contractor declared that this was impossible because he had sublet the plaster work, and supplied all the materials and had not supplied any lime. However, an analysis of the contents of a suspicious looking bag discovered on the work, as well as of the plaster itself, showed the former to be lime and the latter to contain it.

A further cause of trouble is illustrated by another case. In a North-Country town a contractor had been supplied with a cement which was of a slow setting nature, but a very reliable product ; the complaint was that it would not set at all, and the contractor, who was also architect and clerk of works on this job, wanted it removed. I had a good look round and formed my diagnosis of the trouble. I suggested that all his aggregates should be removed—heap No. 1, a Derbyshire greasy limestone, heap No. 2, a Derbyshire spar, and heap No. 3, a Flintshire or Shropshire spar. The presence of sulphur in the two latter ingredients was showing up in the concrete and not only had retarded the setting of the work but was of a nasty yellowish-green hue owing to the sulphur.

PARAFFIN IN CONCRETE TANKS.

An interesting problem recently came before me, namely, that of preventing paraffin from creeping in a concrete tank, and after nine months of periodical trials I came across the right thing. I placed a strip of copper for half its length in a glass of paraffin and found after three days there was no sign of creeping, so I had a copper band made and bent to the dimensions of a model tank. This band was inserted all around the top of the concrete tank, with a perfect joint, showing that the paraffin would creep to the copper but not beyond it.

CONDENSATION ON CONCRETE.

A good deal is sometimes heard about condensation on concrete, and people have sometimes been prejudiced against concrete houses on the ground that they were cold and damp. This, of course, is a fallacy—provided the work is carried out satisfactorily. If concrete walls are finished on the interior with a rough-casting of lime hair mortar and a finishing coat of 1 to 1 lime mortar no condensation will appear. On examining a pair of concrete cottages built on this method fifteen years ago on the East Coast, I could not find a trace of dampness—indeed, they were bone-dry. The outsides were of cement stucco with which a small portion of well-seasoned lime putty was used. In most cases where condensation is experienced it is due to the interior walls being plastered with, perhaps, cement mortar and then finished with some other hard-surface material.

(To be continued.)

MEMORANDA:

Professional Announcement.

Mr. W. Cleaver, M.Inst.C.E., has been appointed Resident Engineer for the Great Western Railway Co. at the Alexandra Docks, Newport, Mon.

Concrete versus Stone Kerbs.

The Borough Surveyor of Poole (Dorset) has reported that a saving of £160 has been effected by the substitution of concrete for Purbeck stone kerbs.

Proposed Concrete Tenements in Bombay.

In view of the proposal of the Bombay Development Department to construct a number of reinforced concrete tenements for the housing of the working classes, a committee of engineers representing local bodies and Government departments is to be appointed to investigate the utility of reinforced concrete construction in Bombay, to examine such structures as have been in existence for more than eight years, and to report on their condition.

Kobe Harbour Improvements.

The Engineer-in-Chief to the Kobe (Japan) Harbour Works has sent us a copy of a booklet fully describing and illustrating the improvements which have been completed within recent years at the port of Kobe. The new work includes a considerable amount of reinforced concrete work, which was described in our issue for August, 1911.

Concrete Cottages at Glasgow.

The Glasgow Corporation has decided to proceed with the erection of a further 500 concrete cottages, which, it is reported, are working out at £17 each less than brick cottages of a similar type.

Concrete Roads.

Mr. Walter E. Bush, M.Inst.C.E. (City Engineer, Auckland, New Zealand), who is responsible for several fine examples of concrete roads which have been laid in New Zealand, recently read a paper on this subject, and the following extract from his concluding remarks should be of interest to all who contemplate laying down new roads. After expressing the hope that he had advanced sufficient evidence to justify all those interested in the improvement of city, urban, and rural streets, to give concrete a very important place in their consideration when selecting a material for the surfacing of roads carrying continuous and heavy traffic, he said other things being equal price would always be a determining factor, and in that connection concrete must be a powerful competitor with other forms of pavement. The objections urged to its use, such as the long period required for setting and consequent diversion of traffic, and the difficulty of effecting repairs, could be overcome if intelligently approached, and the advantages it possessed were so obvious that it could safely be predicted that it had come to stay as an important factor in providing those facilities for traffic which the recent application of mechanically-propelled traction had rendered absolutely necessary. At the same time, he emphasised the necessity for definite limits being placed on the character of, and the axle loads carried by, mechanically-operated or horse-drawn wagons, for it was futile to imagine that a highway could carry excessive axle loads and undergo destructive treatment from unsuitable tyres with impunity. As in all other engineering construction, the load should be defined, and the work to be performed specified before a pavement could be adequately designed to meet the stresses of future traffic, and in the interests of all road users and of the public who found the money to make and maintain such roads excessive loads, high speeds, and unsuitable tyres should be prohibited, and a proper standard agreed upon and adhered to.

The New Pensions Building, Acton.

In our last issue it was inadvertently stated that the structural steel work at the New Pensions Building at Acton was designed by Messrs. Dorman, Long & Co. The steel work was designed by the Structural Engineering Department of H.M. Office of Works in conjunction with the architect, to whose drawings it was manufactured and erected by Messrs. Dorman, Long & Co.

PROSPECTIVE NEW CONCRETE WORK.

ALTON.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £10,000 for sewage disposal works.

BANRY.—*Marine Lake and Sea Wall.*—The U.D.C. has under consideration schemes for the construction of a marine lake at Cow Knap, estimated to cost £10,000, and the continuation of the sea wall at Whitmore, at an estimated cost of £9,000.

BROUGHTON.—*Sewage Works.*—The Wrexham R.D.C. has decided to apply to the Ministry of Health for sanction to borrow £10,000 in connection with the Broughton sewage disposal scheme.

BYFIELD.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Daventry R.D.C. for sanction to borrow £1,550 for sewerage and sewage disposal works at Byfield.

COCKERMOUTH.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £19,200 for sewage and sewage disposal works.

COUNTESSWEAR.—*Bridge.*—Subject to the Ministry of Transport contributing half the cost and the C.C. half the remainder of the estimated sum of £1,200, the Exeter City Council has decided to construct a new bridge over the canal at Countesswear.

EDENBRIDGE.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Sevenoaks R.D.C. for sanction to borrow £10,000 for sewage disposal works at Edenbridge.

GOSPORT.—*Swimming Bath.*—The U.D.C. proposes to construct a lake, footbridge, and bathing huts at Stokes Bay, to extend Forton recreation ground and to build a concrete swimming bath.

HARROW.—*Swimming Bath.*—The Harrow Council has applied to the Ministry of Health for sanction to borrow £9,850 for the construction of an open-air swimming bath.

HERNE BAY.—*Sea Wall.*—The Herne Bay Council has under consideration an improvement scheme for the sea front, which includes a ferro-concrete bathing pool and a reinforced concrete sea wall.

HUDDERSFIELD.—*Sewage Works.*—The Corporation has decided to apply to the Ministry of Health for sanction to borrow £133,300 for sewage works extensions.

HYLTON.—*Bridge.*—The Sunderland R.D.C. is sending a deputation to confer with the Durham C.C. Works Committee regarding the proposed bridge over the Wear between North and South Hylton.

IFFLEY.—*Weir.*—The Thames Conservators have decided to reconstruct and extend the Iffley Weir at an estimated cost of £8,625.

IPSWICH.—*Dock.*—The Ipswich Dock Commission has in view an expenditure of £265,000 for the development of Ipswich Dock.

LEIGH.—*Sewage Works.*—The Southend-on-Sea Corporation has received a further report from Mr. E. J. Silcock approving generally the proposals of the Highways and Works Committee for the extension of the Leigh Sewage Works.

LEITH.—*Dock.*—The Works Committee has approved generally the report of Mr. A. H. Roberts, Superintendent of Leith Harbour and Docks, suggesting the desirability of reorganising the quay and sheds on the south side of the dock at an estimate cost of £20,000.

LITTLEHAMPTON.—*Piles.*—Mr. R. H. King, M.Inst.C.E., in his report on the works necessary at the harbour, recommends the replacement of the wood piling by piles of reinforced concrete.

LLANCEFYN.—*Bridge.*—At a meeting of the Narberth R.D.C. the question of a bridge over the ford at Little Mill was mentioned when it was stated a local contractor had offered to build a stone bridge for £200, or a concrete one for £100.

LLAY.—*Sewage Works.*—The Wrexham R.D.C. has decided to apply to the Ministry of Health for sanction to borrow £5,000 for the Llay sewage works.

LONDON.—(HACKNEY.)—*Road Works.*—The B.C. proposes to undertake road reconstruction work at an estimated cost of £36,400.

LOUGHBOROUGH.—*Sewage Works.*—The Corporation has decided to apply to the Ministry of Health for sanction to borrow £21,215 for extensions to the sewage disposal works.

LOWESTOFT.—*Defence Works.*—The Board of Trade has approved plans for the construction of two groynes on the North Beach, and for the reconstruction of the sea wall.

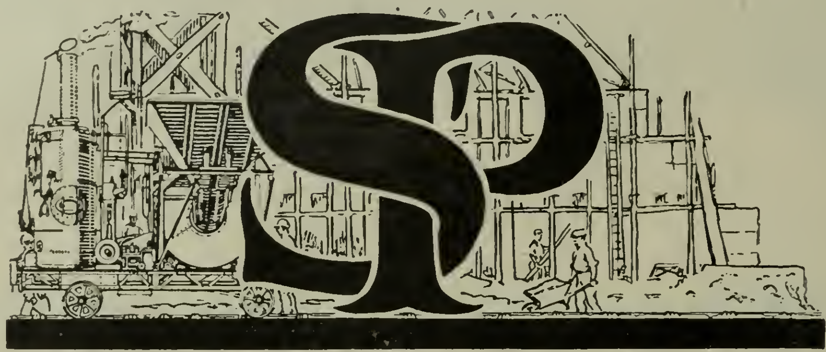
MANCHESTER.—*Road.*—The Ministry of Health has given its sanction to the Corporation Town Planning Committee to borrow £23,945 for the construction of road 29.

MANSFIELD.—*Sewage Works.*—The Ministry of Health has notified the Mansfield T.C. that it is prepared to approve the scheme for the extension of the sewage works.

MERTHYR TYDFIL.—*Road Works.*—The Public Works Committee recommends the T.C. to carry out various road improvement works, at an estimated cost of £61,660.

OLDBURY.—*Gasworks.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £20,000 for gasworks extensions.

OSWESTRY.—*Reservoir.*—The T.C. has decided to apply for a grant towards the reconstruction of the Mount reservoir, estimated to cost £10,000.



POOLE.—*Sewage Works.*—The R.D.C. has received sanction from the Ministry of Health to borrow £10,000 in connection with the Broadstone sewerage works.

PORTH.—*Bridge.*—The Rhondda U.D.C. is proposing the erection of a new bridge and the construction of a new road at Porth.

RICHMOND.—*Bridge.*—The Surrey C.C. Highways and Bridges Committee recommends the erection of a new bridge near the railway bridge.

SHOREHAM.—*Harbour Works.*—A Committee of the U.D.C. has under consideration the question of lengthening the West Pier by half a mile or more.

SMETHWICK.—*Gas Works.*—The Ministry of Health has held an inquiry into an application by the T.C. for sanction to borrow £13,328 in connection with the gasworks extensions.

STAINES.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £5,000 for the extension and improvement of the sewage disposal works.

STOKE.—*Bridge.*—The Surveyor to the Wells R.D.C. has been instructed to carry out the work on the Stoke Moor Bridge either in accordance with his specification or in concrete.

TENDERS ACCEPTED.

BUCKNALL, LINCS.—*Bridge.*—The Horncastle R.D.C. has accepted the tender of Mr. G. W. Horton, of Horncastle, at £198 0*s.* 6*d.*, for taking down and rebuilding in reinforced concrete the bridge near the School at Bucknall.

CHIPPING WYCOMBE.—*Sewage.*—The High Wycombe T.C. has accepted the tender of Messrs. Campbell Kenyon & Co., at £31,167 7*s.* 9*d.*, for the construction of sewage outfall works.

NORTHWICH.—*Sewage Disposal Works.*—The R.D.C. has provisionally accepted the tender of Messrs. Curzon and Noden, of Winsford, Cheshire, at £3,425, for the construction of the Rudheath sewage disposal works.

OAKHAM.—*Wall.*—The U.D.C. has accepted the tender of Mr. J. Simpson, of Braunston, at £55, for the construction of a 60-yard concrete wall 2½ ft. high.

SOUTHEND-ON-SEA.—*Shelters.*—The T.C. has accepted the tender of Mr. A. J. Arnold at £320 for the erection of two shelters on concrete platforms on the Eastern Esplanade.

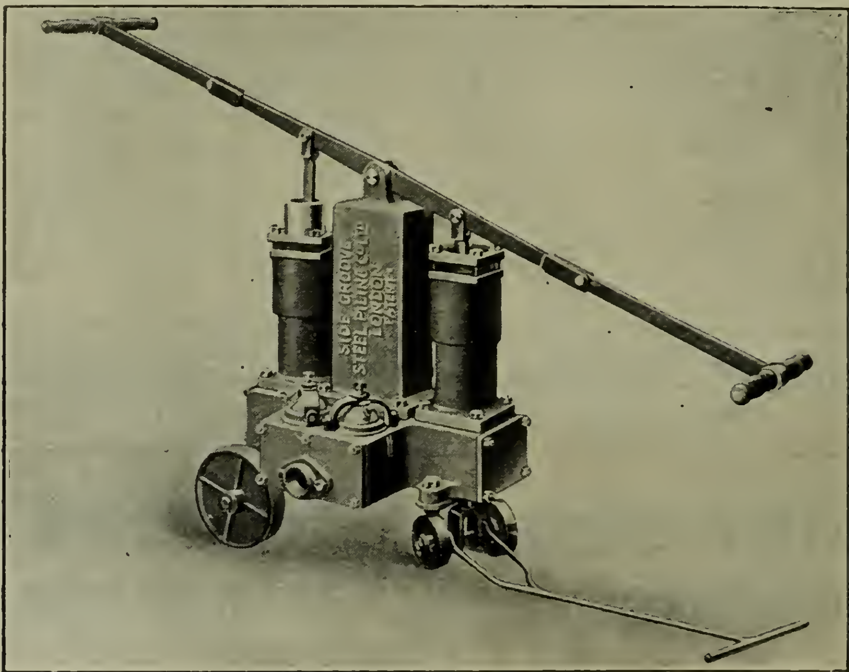
STRETFORD.—*Water Duct.*—The U.D.C. has accepted the tender of Messrs. Smith & Briggs, Old Trafford, at £6,585, for the construction of a concrete water duct.

RECENT PATENT APPLICATIONS.

161,185.—A. S. Buisman: Foundations of structures.
162,287.—C. C. Lyno: Walls and structures of cement bricks.
168,602.—A. C. Matthews: Concrete building slabs.
176,778.—Soc. Industrielle de Materiel D' Entreprise et de Construction: Apparatus for constructing concrete piles.
181,098.—R. H. Rogers: Beams and structural members for reinforced-concrete construction.
181,133.—E. G. Clarke: Machines for making concrete blocks or slabs.
181,408.—W. Marriott, A. W. Roy and A. Ramur: Moulding concrete blocks.
181,422.—E. S. Luard: Concrete construction.
181,424.—S. Raskin: Adjustable form for moulding columns *in situ*.
181,748.—Messrs. E. W. Roberts and L. F. W. Leese: Casting cement or fibro-cement under pressure.
181,754.—Sabulite (Gt. Britain), Ltd., J. Bellingham and W. H. Mc.Candlish: Machines for moulding concrete.
181,763.—P. Pritchard and Midland Construction Co., Ltd.: Moulding concrete slabs or other concrete articles.

TRADE NOTICES.

A new catalogue illustrating their patent cement grouting pump has been issued by the Side Groove Steel Piling Co., Ltd., of 47, Victoria Street, London, S.W.1. This machine has been designed for forcing liquid grout without the help of air compressors or other appliances, and is supplied with or without wheels. The advantages



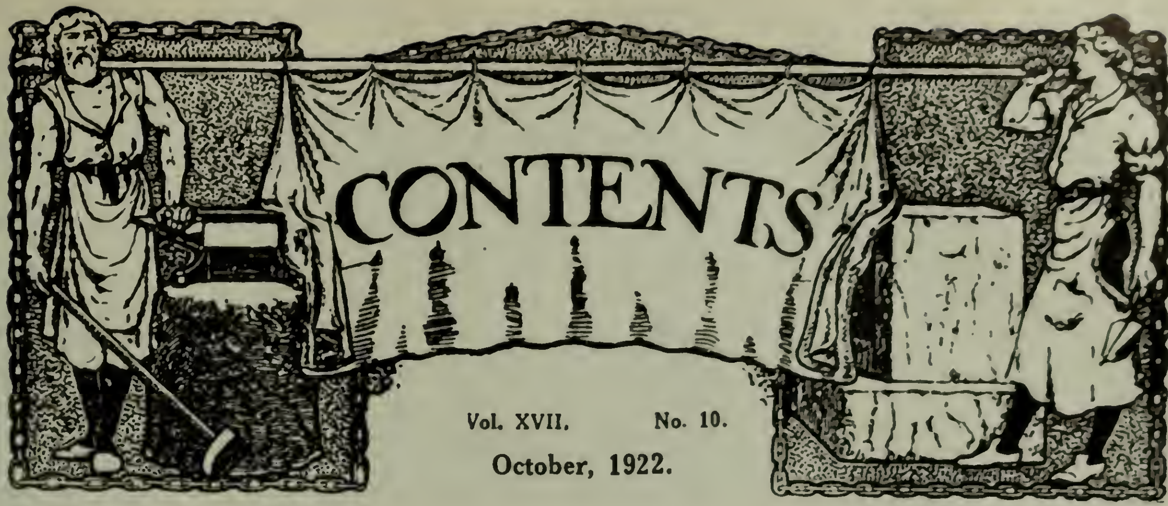
New Cement Grouting Pump.

claimed for this machine (the " Monolith ") include the following :—No air is passed with the grout into the fissures ; no air pockets are formed to prevent the cement grout reaching the interstices of fissured parts ; fissured structures do not have the fissures enlarged by the disruptive action of air delivered at high pressure ; slight pressure only required, usually 30 to 50 lb. being ample ; when required to apply grout in awkward places, the pump may be dismantled and taken through small apertures or into otherwise inaccessible quarters, and reassembling is the work of only half an hour ; it can be suspended on a light platform at the side of or under bridges, viaducts, etc., or wheeled along a quayside, or placed on a railway truck, and owing to its small bulk can be worked in the six-foot way without interrupting railway traffic ; there are no spring or stem valves to become choked ; the machine is worked by two men.

Messrs. Frederick Braby & Co., Ltd., of Eclipse Works, Glasgow, have issued a new series of booklets descriptive of their well-known steel structures. The booklets deal with " Steel Storage Bins, etc.," " Roofs and Sidelights," " Steel Buildings and Structures," and " Eclipse Tanks."

[*Mrs. Phœbe Stabler, Sculptor.*]

"MOTHER AND CHILD." SCULPTURE CARVED IN CONCRETE. (*See p.* 631.)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Ask for leaflet on the Ransome Hand **Bar Cutter** *for cutting Bars of $\frac{3}{4}''$ to $1\frac{9}{16}''$ dia. for reinforced concrete.*

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 10. London, October, 1922.

EDITORIAL NOTES.

MATERIALS AND COSTS.

One of the many directions in which concrete can help the architect in search of ways and means of lessening the cost of building is by its adaptability, no less than its suitability, for use in place of stone for architectural features and enrichment. For centuries stone has been so much looked upon as the traditional material for cornices, string-courses, doorways, windowsills and surrounds, etc., that until quite recently no one seemed to look for any other material. The truth of the old adage that "necessity is the mother of invention" has been proved up to the hilt during recent years, and the necessity for counteracting the increased cost of every commodity which goes to make up a modern building has caused architects and builders, in common with the leaders of other industries, to look beyond accepted methods and the usual way of doing things in their efforts to keep the cost of building down to a figure which will attract the building public. As a result of this close scrutiny of relative costs concrete has become recognised as the best and cheapest material for permanent buildings, and for certain classes of buildings it is now used almost to the exclusion of every other material, but the economies which can be made by the use of concrete in conjunction with other building materials is not always realised. In a modern building, whether the walls be of concrete, brick, or stone, it is the rule rather than the exception to find a reinforced concrete floor ; in the exteriors of stone or brick buildings, however, the money-saving possibilities of concrete are not taken advantage of to anything like the extent they might be. A fine concrete, made under efficient supervision, is practically unrecognisable from stone, certainly not after a brief exposure to the weather and soot-laden atmosphere of our large towns, and its use in conjunction with natural stone or brick in no way detracts from the appearance of a building. If any prejudice ever existed against the use of concrete for such purposes (and surely a prejudice in favour of a material which unnecessarily adds to the cost of a building is unfair to a client who wants his building as cheap as possible ?), it cannot fail to disappear in face of figures now available showing the very large sums which have actually been saved by its use in place of stone. The new Pensions Building at Acton, illustrated in our August issue, is an outstanding example. In this building, 540 ft. long by 247 ft. wide, the architect and structural engineer working intimately together designed a concrete cornice, with a projection of 4 ft., which has worked out at about one-tenth of the cost of a cornice of the same dimensions in stone. (On p. 664 in this issue we give some detail drawings of this cornice, which has several features of interest.) A recent issue of a Canadian contemporary contains particulars of a similar instance in the Royal Jubilee Hospital now in course of erection at Victoria, B.C.: "A feature of this work," it is stated, "is the reinforced concrete cornice suggested by the contractors as an alternative to the stone cornice specified by the architects, and the acceptance of which led to a saving of about 15,000 dollars." It is not only in cornices that saving can be effected without any sacrifice of appearance; rusticated bases, for instance, can be made of concrete and the roughened face produced at the one operation of moulding, all mason's work, except for the laying of the blocks, being eliminated; door and window mouldings, festoons, and other decorations without exception can be similarly cast in concrete, either *in situ* or away from the site, and in all cases the cost is but a fraction of carved stone work. The subject is one which should receive the serious attention of all interested in the revival of the building industry, which can be achieved only by making building an attractive proposition to the investor.

STANDARDISATION IN THE PROPORTIONING OF CONCRETE.

THE faculty for standardisation which exists to a high degree in America is well illustrated by Bulletin No. 9 of the Structural Materials Research Laboratory of Chicago, which presents a number of tables showing the proportions of cement, sand, and aggregate required to produce concretes of specified compressive strengths. The tabulation is by Messrs. Duff Abrams & Stanton Walker, and embodies the results of seven years' work, including about 100,000 tests. Investigations of such a scope certainly warrant generalisation being attempted, and the conclusion has been reached that the strength of a concrete mixture depends upon the ratio of water to cement. The strength of the concrete decreases as the water-cement ratio increases. It follows from this that all combinations of cement, sand, and aggregate which require the same amount of water per unit of cement to produce a given consistency will have the same strength, and the result is seen in the tables, which give 220 mixtures for each specified strength of concrete at 28 days. As an example, a concrete of 3,000 lb. per sq. in. compressive strength can be produced with mixtures ranging from a dry mix of 1 part cement to 6·6 parts sand and aggregate (when the latter is graded up to 3 in.) to a wet mix of 2 parts cement to 1 part sand when the latter entirely passes a 30-mesh sieve. Fine aggregates require more water to produce a given consistency, and therefore more cement is needed to produce a given strength than would be required with coarse aggregate. According to this theory of the essential importance of the water/cement ratio the lower strengths of the poorer concrete mixtures are not due to the additional material the cement has to cover but to the extra water (per cement unit) which must be used to produce a workable mixture.

The consistency of the concrete is determined by the slump test and the application of the tables requires testing for fineness of the sand and aggregate on sieves from 50 meshes per linear in. downwards. It is, of course, assumed that the cement is of standard quality and that the aggregate is structurally sound. Six separate tables are given for compressive strengths ranging from 1,500 to 4,000 lb. per sq. in. in gradations of 500 lb., and 220 possible mixtures are given for each strength, namely, four different consistencies—from ½ in. to 10 in. slump—with 55 different finenesses of sand and aggregate. The tables have a double value: in the first place they enable engineers and contractors to arrange their concrete mixtures so as to produce a known strength; and, second, by means of the figures it may be possible to select aggregates with a view to economy in cost of the finished concrete. An example of this latter possibility may be cited: a cubic yard of concrete containing sand passing the 16-mesh sieve and aggregate ranging from ¼ in. to ¾ in. requires 1 cwt. more cement than a cubic yard containing sand up to ¼ in. grain and aggregate from ⅜ in. to 1½ in. to produce the same strength.

The publication marks a further advance in the scientific treatment of concrete, and will be of particular value in the United States where the tentative standard specification for concrete puts the onus on the contractor of producing concrete of a given strength. British practice has not reached this stage, but no doubt in due course the principle of proportioning concrete to give a specified strength at a minimum cost will be adopted.

Some of the tables are given on pp. 665–669 of this issue.

CONCRETE IN THEATRE CONSTRUCTION AND DECORATION.

THERE was matter at the International Theatre Exhibition, recently housed at the Victoria and Albert Museum and now visiting the provinces, to interest persons of the most diverse pursuits; and not only those who are by profession intimately connected with the stage, such as actors, scene designers, producers and managers, but also architects, painters, craftsmen and engineers of all kinds—electrical, ventilating, hydraulic, and concrete—realised, perhaps for the first time, how varied are the elements which synthesise into a modern dramatic performance. For the informed visitor one fact must have emerged distinctly, and that is the pre-eminent suitability of concrete for modern theatre construction. Its qualities, notably its strength, its resistance to fire, its adaptability to varied forms, and its endurance, are just those which the modern theatre requires. The English exhibits included very few designs of theatre buildings, but in the German and Austrian rooms were many examples of both, and it was evident, although not specifically stated, that concrete for the most part was the material either used or contemplated. Continental architects are giving much thought to the question of theatre building, realising that a change is necessary in its design and equipment to meet modern ideas. The whole position of the theatre on the Continent, where it is considered a legitimate matter for State and municipal enterprise, differs from that in England, and for many years there has been a close study of Continental methods by English designers, managers, and lighting experts. Hitherto, however, but little study has been given to the buildings themselves, which are of special interest to the concrete designer. Among important factors which influence theatre design are the new methods of lighting, most of which are derived from that of Signor Fortuny, and require a hollow cylindrical or spherical back to the stage. Sometimes this is a collapsible arrangement of silk stretched on a steel frame, sometimes it is an integral part of the building, and this has led to experimenting with a circular theatre, a shape for which concrete is particularly suited. The auditorium, no less than the stage, is undergoing changes, and the tendency is towards one large ramp and a shallow gallery rather than successive horse-shoe tiers. Here again concrete, by reason of its strength and suitability for cantilever construction, and for providing immunity for the audience from visual obstacles, is the most suitable material. Finally, it is realised that both internally and externally a quiet, restful, and dignified treatment is required rather than a veneer of applied splendour ; the performance is the focal point to which all else must be subservient. Concrete is a material which lends itself particularly to that kind of treatment, for both its surface and its line can be made attractive by those who have studied its indigenous uses. A characteristic of the theatre plan are its component parts of stage, dressing-rooms and storage-rooms, auditorium, circulation, and foyer. These form distinct blocks which in their massing provide a real architectural interest. And concrete, by reason of its plasticity, enables these parts to combine and intersect in a manner impossible with less pliable materials. This is a fact of which Continental designers are fully cognisant, and constant use is made of the ellipse and other curves skilfully intersecting into a geometrical cohesion. The constructional side of the theatre movement is a matter which offers infinite attraction and scope to the concrete designer.

UTILITY, ECONOMY, BEAUTY.

THE statement in a contemporary that " Railway engineers have never been in the habit of placing art above economy and utility " is not without interest, and we are inclined to hope that they never will. But there is very false reasoning in such an argument, because it suggests that utility and economy are in some way opposed to beauty, which, rightly understood, they are not. To separate art from use and economy in such a way is quite a wrong method of thinking about it, though we may very well excuse any one for doing so on account of the popular misconceptions prevailing about the nature of art. The idea that art is an addition necessarily outside of economy or utility, and cannot therefore be included where these have to be considered, is a fallacy of a most unfortunate kind. There was in comparison with to-day very little money when the vast cathedrals of the middle ages were raised. We must learn to understand art in better ways. Time will show, is already showing, that it pays the constructor in concrete to give attention to appearance, to consider the claims of beauty in his design, because it is not necessarily opposed either to utility or economy (that idea is largely due to our false thinking about it) and it will do much to promote the prestige of the material. The satisfaction of the eye as well as the mind, the claims of beauty as well as use, are incorporated in architecture, and we do not think that the builder in ferro-concrete will wish to do less justice to his task than will sustain its claims as architecture—for the prestige which is fostered by a realisation of what is due to the amenities of public buildings will be a contribution to its more extended use.

THE CONCRETE INSTITUTE.

AT an extraordinary general meeting of the Concrete Institute, held on September 28, it was decided by 110 votes to 13 to change the title of the Concrete Institute to " The Institution of Structural Engineers," which will incorporate sections dealing with concrete, steel, brickwork, masonry, timber, and earthwork, each section under its own chairman. A number of resolutions consequential on the change in title were passed, and these will be put up for confirmation at a further extraordinary general meeting to be held on October 19.

SCULPTURE IN CONCRETE.

By REGINALD HALLWARD.

THOUGH ancient sculpture was executed in concrete we are concerned here with its modern application, which is adding a most adaptable material to the more traditional stone, brick, and wood. At the present time the subject of the use of concrete for sculptural purposes is receiving a good deal of attention. The results already obtained justify the belief in the great possibilities of the material. Whether for interior work or the outside of buildings there seems no limit to the possibilities of its application to architecture, and if the work be executed *in situ* under the actual conditions imposed by the material, on one side, on lighting and purpose on the other, these considerations, if properly regarded, should lead to beautiful results. The craftsman executing his work in this way should find scope, whether monument, frieze, cornice, or panel, for all manner of delightful treatment. There is no reason, for instance, why carved ornament such as that on the sides of the tomb of William de Vallence, or that on the front of Queen Elizabeth's tomb in Westminster Abbey, should not be just as much applicable to concrete. No doubt the craftsman in concrete on looking at the romance of deeply-undercut masonry ornament, would desire to emulate the incomparable richness of such work, and would gaze with envy and admiration at the beautiful deeply-undercut cornice to the noble screen which divides the Confessor's chapel from the Sacrarium in Westminster Abbey. The design which the decoration is to take having been planned, the cornice or frieze in which this feature was desired could be blocked out with such necessary strengthening as would permit of this more unattached treatment. I venture the suggestion as one to be regarded with an open mind. At the same time I am not concerned in trying to force concrete outside its own resources, which offer ample scope in themselves. We see such wholly adequate and admirable results already in the concrete sculpture of Mrs. Phœbe Stabler that there need be no fear on this account.

[*Mrs. Phœbe Stabler, Sculptor.*]
CARVED HEAD IN CONCRETE.

Let us suppose, for instance, a concrete screen, to divide off a chapel or hall, erected with the main features blocked out ready for the additions of ornament, cornice, mouldings, panels, etc., to be carved on the screen itself. One can well imagine something very personal and characteristic would result from it—and if a gifted sculptor were employed one might look for something very lovely ; the resources of the material yielding themselves up to express that which was wholly original and characteristic. In such a way there would be included all the advantages which result where treatment really grows out of and is the outcome of the actual situation, wedded to all the conditions which the lighting, scale and general circumstances connote.

Concrete, like any other material, only yields its characteristics to abilities fine enough to extract them, and only the vivacity and directness of Mrs. Stabler's work made the result possible. But her sculptural sense is so sure that the human interest is always paramont. Though well clothed in the restraints of art, as well as a certain archaism at times, treatment is never carried past the limit which would obstruct this primary human appeal—the "Carved Head" illustrated in this article, the swift accomplishment of a few hours, is replete with these constituents ; of that fine appreciation which governs her work. "The Dreamer" also illustrated (and the photo does not adequately do justice to the original) is another instance of that intuitive perception of what is due to nature and what is due to art. Mrs. Stabler's work in carved concrete is of exceptional beauty. Concrete in her hands has justified itself as the fit vehicle of her inmost visions.

[*Mrs. Phœbe Stabler, Sculptor.*]
"HEAD OF A GIRL" (CARVED IN CONCRETE).

On thinking of the many applications of such fine work for sculpture, either in relief or in the round, one desires to see full use made of the opportunity, for the road Mrs. Stabler has opened out for herself should have a considerable influence on the future prestige of concrete building. How much more logical and satisfactory it would be if the present intention to face the concrete building in Exhibition Road, South Kensington, with brick were superseded by a scheme of concrete decoration, which would be of far more direct application to it, far more interesting in result, and probably far less expensive? It is, however, interesting to notice the rapid development of the use of concrete for permanent buildings, and it is satisfactory to know that at the Empire Exhibition now in course of preparation at Wembley the buildings which are being erected will be of permanent character. We shall not get fine sculpture work done for tentative purposes without the security of a permanent aim.

Nothing is more desirable than the closer union of industry with art, that it may be seen what they owe to each other, and how much the arts are concerned in identifying themselves with industry; not, of course, as yielding any of the just prerogatives which belong to them, but in the understanding that art reaches its best self only when its activities are closely concerned with and move through the national life. When thus identified art will influence their whole character. We are passing through a stage when it is still thought that to make use of art for the benefit of commerce is an adequate conception of its true relation. This is not so, and the desire must be for its own sake, and not for the economic advantages lying in such relation, though these will naturally occur. The motive of our action is of the first importance, because if sought with the wrong motive we shall also seek it in the wrong place. Only if we seek our objects in the right way will art reach that relation to industry, and industry to art, which exalts them both.

[*Mrs. Phœbe Stabler, Sculptor.*

"THE DREAMER" (CARVED HEAD IN CONCRETE—OVER LIFE SIZE).

As there will probably be a great deal of opportunity in the future for architectural decoration on concrete buildings, including statuary, panels, friezes, etc., it is an important point in taking full advantage of an artist's work to understand its varying scope and apply it in the best way. In one case it may be that the talent is towards more abstract decorative and design work, in which human interest is less direct, as in devices, coats-of-arms, and much other applied ornament; in another the human interest will predominantly prevail. The distinction between fine and applied art has a very true meaning, and leads us to understand and apply the artist's talent in the best way. In the case of a sculptress like Mrs. Stabler, to reach the incommunicable quality of her fine work it will require herself directly over it all. Any delegation or working through others, except as it will facilitate this, were to take from her work its most important attribute, and we should wish such a talent to be occupied on statuary or friezes in which this direct first-hand relation were retained. It is an end in itself; its application primarily to itself, and when architecturally applied it should be to the most important occasions, and we should think of it primarily as fine art. In another case there will be evidence that the human interest is less direct, more abstract. Ornament, the craftsmanship of which applies to so many other forms of decoration, may be applied more indirectly and can be organised through a staff, such as the artist's working with a firm, a highly desirable development when carried on in the right ways. In such a case his work can be executed through others, and be multiplied under his more highly qualified craftsmanship and direction. The distinction between these differing abilities is too much obscured. Both have their place and belong to each other, but it has been ignored in so much "arts and crafts" propaganda and the aim must be rather to define more truly their relationship, that the scope of one may not overrun the other, or obscure in our mind the august character of the incommunicable quality which we associate with fine art, and keep this elder sister relationship with the rest.

GARDEN WITH CONCRETE TABLES AND SEATS. (*See p.* 663.)

ADHESION OF STEEL AND CONCRETE, AND PRESERVATION OF BRIGHT-DRAWN STEEL EMBEDDED IN SLAG AND OTHER CONCRETES.

By F. C. LEA, D.Sc., M.Inst.C.E., M.I.Mech.E., and R. E. STRADLING, M.Sc., Ph.D., A.M.Inst.C.E., A.M.Am.S.C.E.

THERE appears very little doubt that with certain precautions slags can be used to form the aggregate of very good concrete. In fact, the published data indicates that usually a much stronger concrete can be made with this material than with broken stone or gravel, but unfortunately quite a number of failures have also followed from its use.

In a blast-furnace slag we have a compound or series of compounds of a similar nature to Portland cement, but with a lower percentage of lime and, usually, a higher percentage of alumina. Finely ground slag will in itself act as a cement, and has been so used in some cases with great success. Unfortunately there is quite often a comparatively large amount of sulphur present, and this is usually credited with being dangerous.

It would seem doubtful from previous experiments on high gypsum contents whether there is really very much to be feared from the amount of sulphur present

FIG. 2. AS FIG. 1 (SHOWING THE BADLY-RUSTED CONDITION OF THE BAR OUTSIDE THE CONCRETE).

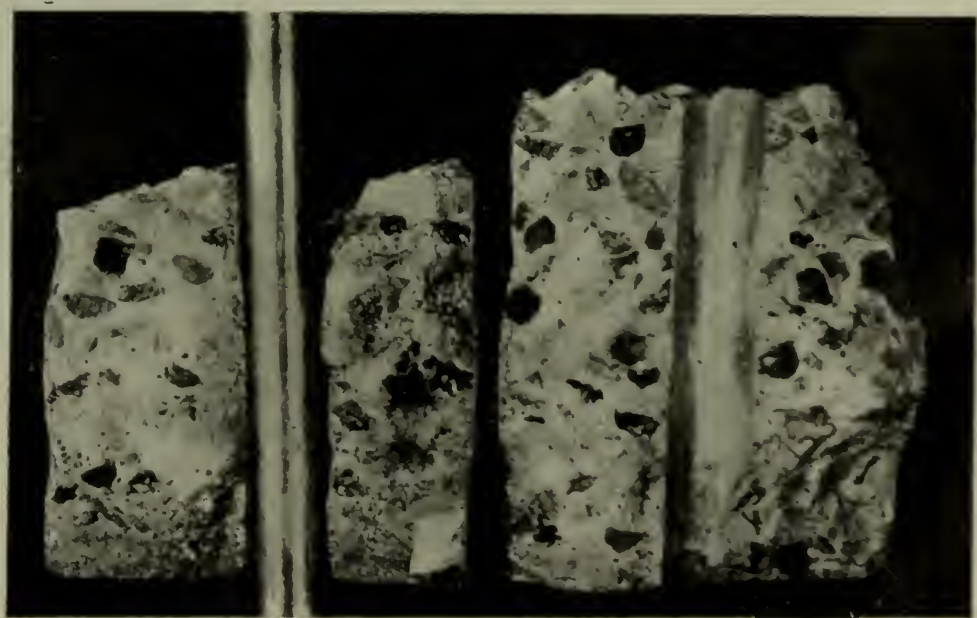


FIG. 1. SLAG CONCRETE AFTER SIX YEARS' EXPOSURE TO WET CONDITIONS, BROKEN TO SHOW STEEL BRIGHT. The part of the Bar outside the Concrete is shown in Fig. 2.

in the average slag—if it is present in the form of gypsum, and it is quite likely to be partially present in this form after weathering for some time on slag heaps. From experiments of Dr. J. E. Stead, F.R.S., it seems certain that an alkaline solution is always obtained with blast furnace slags, and this might help to protect steel from rusting, though it would be interesting to know whether this extra alkalinity is comparable with that of the cement itself.

About seven years ago experiments were started at Birmingham University to ascertain values for the adhesion between bright-drawn steel and concrete, and the blocks (cylindrical) which were cast for this purpose have been exposed to water and the weather for the past six years. The composition of the blocks is shown in Table I.

Lengths of bright-drawn steel 15 in. long 1⅛ in. diameter were cast into blocks of concrete 12 in. long. And some of these blocks, made of concrete with various materials as the coarse aggregate, have at various times during the past two years been broken open. In all cases the steel was as bright as when placed in position. In *Figs.* 1 and 2 photographs are shown of an actual example. The concrete in this case had slag as the

TABLE I.

ADHESIVE AND CORROSIVE TESTS OF BRIGHT-DRAWN STEEL AND CONCRETE.

Table showing adhesive stress at slipping of bright-drawn bars 1⅛ in. diameter, embedded in 6 in. diameter blocks about 12 in. long. The bars were pushed through the concrete.

No. of block.	Date of test.	Age in days.	Mixture.	Moisture. %	Aggregate.	Length of bar in block. ins.	Load at which slipping took place (tons).	Adhesive stress, lb. per in. length.	Adhesive stress, lb. per sq. in.	Age (days) of crushing blocks.	Crushing stress, lb. per sq. in.
1	14/10/15	259	1 : 1 : 2	10	Slag 1″ to ½″	12·375	2·51	457·1	129	141	2513
2	,,	,,	,,	11	,,	,,	1·848	344·4	95	,,	2362
5	15/10/15	267	1 : 1½ : 3	9	Slag 1″ to ½″	,,	3·195	581·8	164	134	2962
6	,,	,,	,,	10	,,	,,	3·348	609·7	172	,,	2385
9	,,	269	1 : 2 : 4	8	Slag 1″ to ½″	12·25	4·436	816·0	229	132	2780
10	,,	,,	,,	9	,,	12·125	3·227	599·7	169	,,	2555
13	18/10/15	283	1 : 1 : 2	8½	Gravel 1″ to ½″	12·375	2·463	448·5	126	116	2605
14	,,	,,	,,	9½	,,	,,	4·568	831·8	234	,,	2610
										113	2090
15	,,	280	1 : 1 : 2	8½	Gravel ½″ to ⅛″	,,	2·438	444·0	125	117	2410
16	,,	284	,,	9½	,,	,,	2·298	418·5	118	137	3225
17	,,	305	1 : 1½ : 3	8	Gravel 1″ to ⅛″	11·656	2·82	545·2	154	136	2310
18	,,	304	,,	9	,,	12·25	3·671	675·3	191	136	3030
19	,,	,,	,,	8	Gravel ½″ to ⅛″	,,	2·723	500·9	142	116	2010
20	,,	284	,,	9	,,	,,	2·245	413·0	117	135	2358
23	19/10/15	308	1 : 2 : 4	6½	Gravel ½″ to ⅛″	11·781	2·671	510·9	144	135	2513
24	,,	,,	1 : 2 : 4	7½	,,	11·728	1·998	383·9	108	139	4551
25	,,	266	1 : 1 : 2	11	Granite chips	12·25	3·976	731·4	207	139	3538
26	,,	,,	,,	12	,,	12·375	3·239	589·8	166	128	3240
27	20/10/15	278	1 : 1½ : 3	9	,,	12·25	3·146	578·7	163	128	3625
28	,,	,,	,,	10	,,	,,	3·712	682·8	193	112	3240
29	,,	281	1 : 2 : 4	8	,,	,,	over 4·3	791·0	224	125	2650
30	,,	,,	1 : 2 : 4	9	,,	,,	3·058	562·5	159	138	2218
21	,,	308	1 : 2 : 4	6½	Gravel 1″ to ½″	11·5	2·998	587·5	166	138	1708
22	,,	,,	,,	7½	,,	10·75	—	—	—	—	—

coarse aggregate, whose chemical analysis is as under.

ANALYSIS OF BLAST FURNACE SLAG.
(*Mr. Hudson.*)

Silica (SO_2)	39·78	per cent.
Alumina (Al_2O_3) . . .	17·70	,,
Lime (total) CaO . . .	31·30	,,
(Includes some S as CaS)		
Manganese oxide (MnO) .	1·72	,,
Magnesia (MgO) . . .	6·92	,,
Ferrous oxide (FeO) . .	1·26	,,
Sulphur (S)	1·32	,,
	100·00	,,

An examination of these "slag" concretes after breaking shows one point very strikingly. The fracture always goes *through* the large aggregate and not around it. In the case of the other aggregates, such as gravel, broken stone, etc., the fracture occurs in the mortar around the stone. Since the strength of slag concrete is usually slightly greater than that made with broken stone, it can fairly be assumed that the adhesion between the slag surfaces and the cement mortar is greater than that between the latter and natural stone. As a slag is somewhat similar to a cement clinker it would be of interest to inquire whether the extra adhesion is due to the hydration of the slag surfaces.

In Table I is given the result of the adhesion tests. It will be seen that these were carried out about seven years ago. The adhesive stress for the bright-drawn steel bar is less than might generally be expected from ordinary rusted bars, and, as usual in such tests, there is marked variation.

After these were tested nine other blocks were made of a rich 1-1-2 mixture, gravel $\frac{1}{8}$ in. to $\frac{3}{4}$ in., and 10 per cent. of moisture. Blocks 1 to 5, Table II, were made on one day, 6 and 7 on another, and 8 and 9 on another. The results of the tests are shown in Table II. Although the concrete and steel had been moved relatively to each other, the actual distance between them was too small in any case to allow moisture to penetrate. At the time when the blocks were broken open, i.e., at different times during the past two years, all the ends of the bars projecting from the concrete blocks were badly rusted, while the portion of the bars in the mass had been perfectly protected.

CONCRETE TABLES AND SEATS. (*See p.* 663.)

TABLE II.

Number of Block.	Age (days).	Adhesive stress (lb. per in. length).	Adhesive stress (lb. sq. in.).
1	97	582	144
2	97	503	162
3	97	707	200
4	97	570	161
5	97	853	240
6	94	567	160
7	94	1008	286
8	98	1353	380
9	98	1314	370

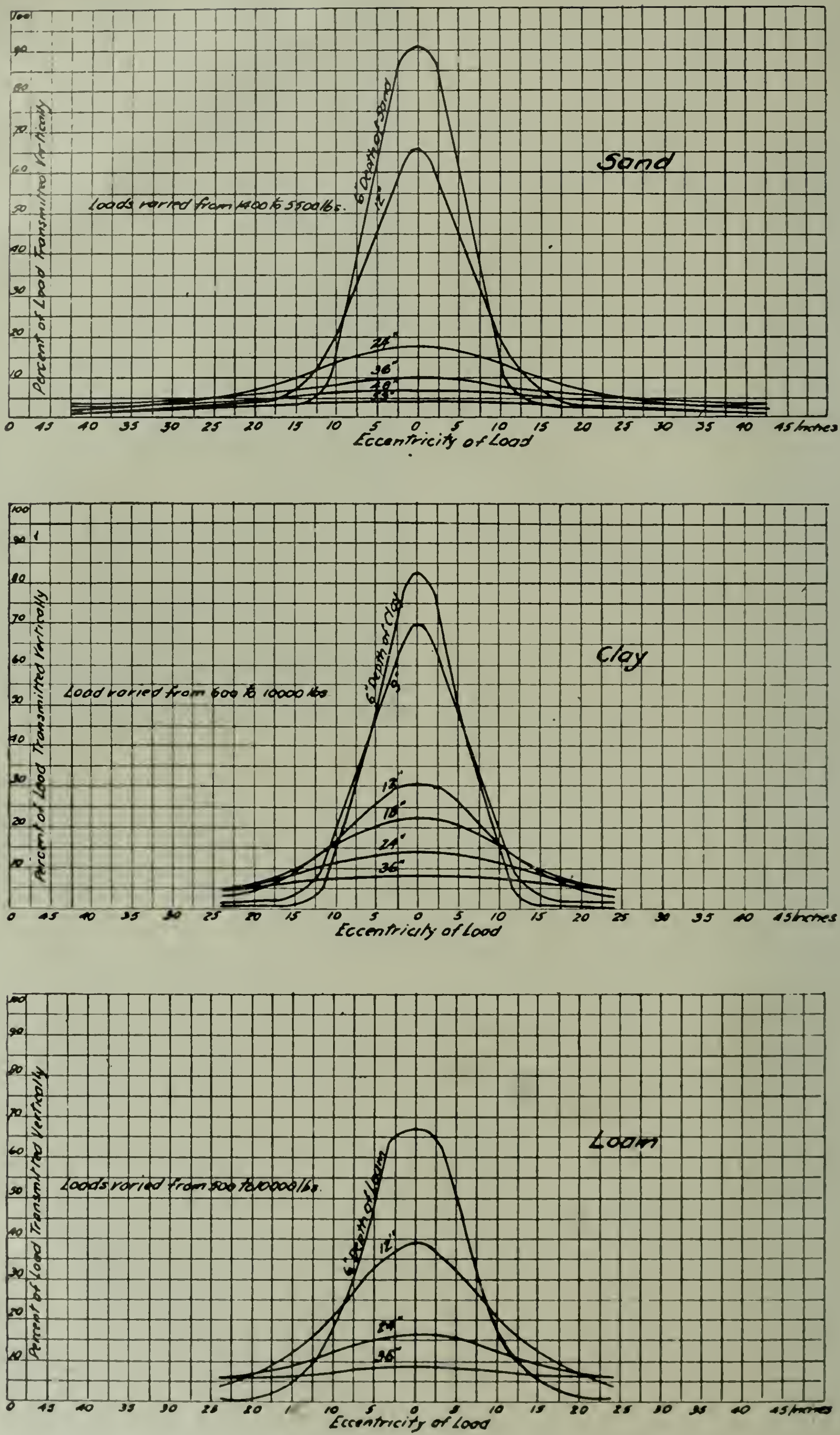


FIG. 1. Curves Showing Per Cent of Load Transmitted at Various Distances from Center for Different Depths of Soil.

METHOD OF ERECTING FOUNDATIONS AND BUILDING SIMULTANEOUSLY. (*See p.* 639.)

A METHOD OF ERECTING FOUNDATIONS AND BUILDING SIMULTANEOUSLY.

"PRETEST" PILES AND THE "BULB OF PRESSURE."

By A. E. WYNN, B.Sc., A.Am.Soc.C.E.

In the June number of this Journal the writer described the construction of the "Hide and Leather" Building, an eighteen-story all-reinforced concrete structure built in New York City. In this article the method of foundations by "Pretest" concrete piles used in this building is more fully described.

In the previous article it was mentioned that the success of this system depended upon the so-called "bulb of pressure" set up in the soil beneath the bottom of the piles. It will therefore first be necessary to trace the origin of this theory and to describe the experiments from which it was deduced.

Considering the importance of this subject, we know far too little at the present time about the pressure of earth and the transmission of pressure through earth from a superimposed load. All mathematical formulæ in common use for earth pressure assume that the earth is a granular material with certain angles of repose and no cohesion or elasticity. We know now, however, that this is not altogether true. We know that earth under a load behaves as an elastic solid and therefore possesses cohesion, and that pressures are transmitted through it as through other elastic bodies. If the assumption of a granular material with no cohesion were correct, earth pressures would increase with the depth. How then can we explain that the pressure on sheathing in a trench or pit does not increase with the depth, or that the pressure on top of a tunnel or culvert is no greater at a depth of 100 ft. than it is at 500 ft., assuming the same cross section of tunnel and soil free from water?

It is a well-known fact that in a sheathed trench or pit in dry material the maximum pressure occurs at about half the height; below this point the pressure decreases, and there is actually more pressure on the upper half than on the lower half of the sheathing. These facts can only be explained by assuming that arch action takes place, and that therefore the earth possesses cohesion and transmits pressures as does an elastic body.

However, we are not concerned here with earth pressure but with the transmission of pressure through earth due to a superimposed load, and the above instances are only mentioned as being well-known facts in the support of the theory of the cohesive and elastic properties of earth.

During the last few years there has been quite a lot of investigation in the United States on this elastic theory in connection with tunnel design, the pressure on sheathed trenches, the stability of deep cuts in mining, and the pressure transmitted from railroad ties, etc. Only those investigations that bear directly on the subject of pile foundations are mentioned here.

In 1914 and 1915 experiments were conducted at the Engineering Experiment Station of Pennsylvania State College, in conjunction with the State Highway Department, to determine the distribution of vertical pressures through a soil, with the object of gaining information for the design of culverts and subways, etc. The apparatus used consisted of a large wooden box, 5 ft. deep, with a 12-in. square hole in the bottom, fitted with a loose board called the "weighing strip." This loose board transmitted any pressure upon it to an ordinary platform scale. The box was filled to a certain depth with the soil to be tested, a 12-in. square wooden loading strip was carefully embedded in the upper surface of the soil and loads were applied to it by means of a calibrated hydraulic jack acting against an overhead I-beam. Any load applied through the jack would thus be transmitted through the soil to the weighing strip, and the vertical pressure in the soil could be read from the scales.

The relation of the difference between the readings of the platform scale before and after applying the load to the weight of the load obtained from the pressure-gauge on the jack gave the proportion of the load transmitted vertically through the soil. The distribution of the vertical pressure was obtained by varying the position of the loading strip and the depth of the soil. When the loading strip was vertically over the weighing strip the maximum vertical pressure was transmitted. As the loading strip was moved left or right of the centre up to a maximum eccentricity of 42 in. the vertical pressure transmitted to the weighing strip decreased.

To obtain the pressures at various depths in the soil the box was filled to heights varying from 3 to 59 in., and tests were made with the complete range of eccentricity at each height. Sand, clay, and loam were tested to obtain the relation of the transmission of pressure through each. A series of curves was then plotted showing the vertical component of the pressure transmitted at different depths and with different eccentricities, each point representing the average of several readings.

These are given in *Fig.* 1. The loads used were those that would actually occur in practice on a foundation varying up to 5 tons per square foot. These curves give some very interesting information on the transmission of vertical pressure in a soil. It will be seen that for all the soils the curves show the same characteristics. This similarity of the action of different soils under pressure has been observed in numerous other experiments, leading to the conclusion that all homogeneous soils will act in a similar manner when under pressure. As the depth of soil increases all the curves flatten out, showing greater distribution of pressure and less intensity; at a depth of 36 in. the vertical pressure transmitted is in no case over 10 per cent. of the load. There is a marked concentration of stress immediately beneath the load and a rapid falling off in intensity below a depth equal to the width of the load. It will be seen also that for small depths there is a rapid and uniform falling off in the stress transmitted until an eccentricity is reached equal to the width of the load, from which points the pressures decrease gradually and are never greater than 20 per cent. of the load. For depths up to 24 in. sand gave the greatest pressures, but for greater depths the percentage of the load transmitted was about the same for all soils.

About the same time these tests were being carried out experiments were being made on the penetration of piles in different soils during the construction of the William Street Subway in New York by Mr. J. F. Greathead, engineer of the Public Service Commission, which is responsible for the building of subways. Mr. Greathead plotted the curves in a different manner, giving for the first time the so-called "bulb of pressure" (*Fig.* 2). If on a cross section of the soil through the centre of the load we join up the points of equal pressure we obtain the curves in *Fig.* 2. These curves show very graphically the bulb of soil that forms beneath the load, radiating the pressures in all directions, to a limit where there is no effect on the soil from the load. If the load is a pile, as the weight on it increases the interior friction in the soil increases until a point is reached when the lateral flow will stop because of this friction, and the soil will compress until at any point it will just stand the pressure, depending upon its distance from the centre of the pile; then the pile will sink no farther under that particular load.

It may be seen how a heavily loaded pile can be supported; as the load is increased the bulb spreads it over a greater area until the unit pressure is reduced to a value the soil can sustain without settlement. Thus, each pile forms its own spread-footing, and a group of piles would form a large spread-footing by the overlapping of the individual bulbs of pressure, transferring the load to a layer of soil beneath the piles. Little or no settlement will take place if the bearing value of the whole area is sufficient. It will be seen that increasing the area over which the piles are driven will be more efficient than increasing the number of piles in the original area. It will be noted from the position of the lines of pressure (very close together at the top and farther apart at the bottom) that the earth behaves as a true elastic solid.

The existence of a bulb of pressure has been further proved by photographing it with a camera placed before the glass front of a box containing sand under pressure. In these photographs the moving grains are elongated in the direction of motion, showing very clearly the lines of flow, which are at right angles to the lines of equal pressure in *Fig.* 2.

More interesting evidence on the distribution of pressure in a soil is given in the report of the American Society of Civil Engineers' Committee on Stresses in Railroad Track (Nov. 26, 1919, published in the *Transactions*). From this report

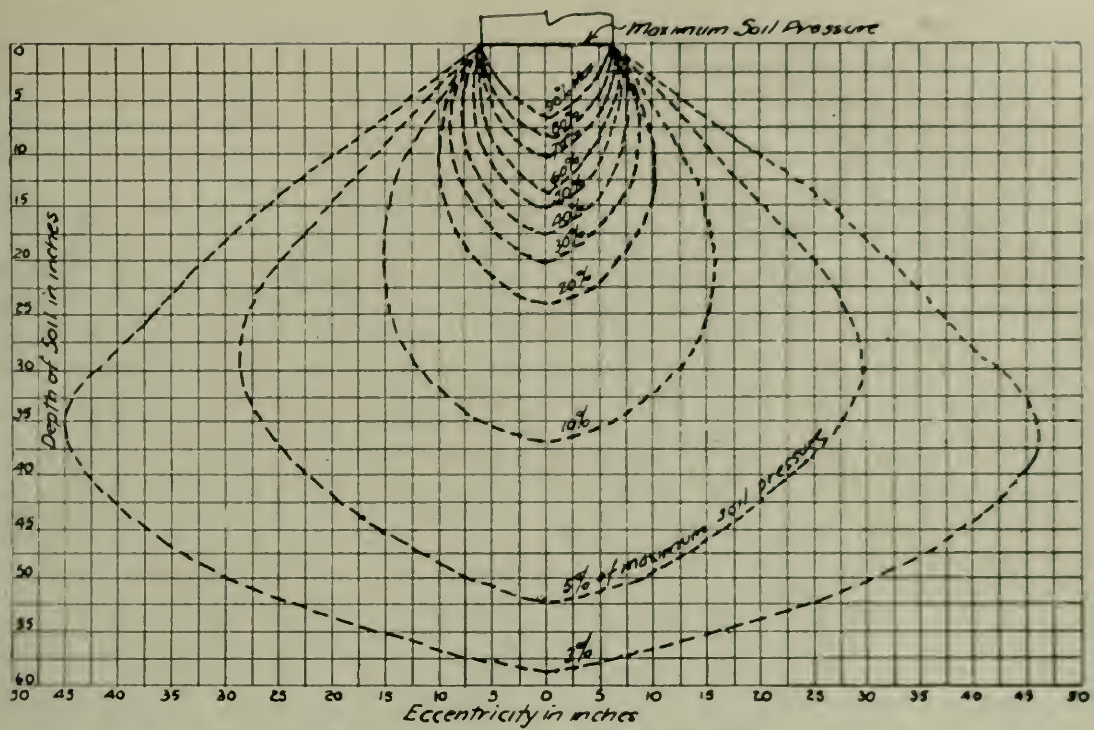


FIG. 2 The "Bulb of Pressure" showing Distribution of Vertical Soil Pressure under a 12" Pile in Sand.

Fig. 3 is taken, showing the bulbs of pressure formed beneath a loaded railroad tie. The lines represent contours of equal vertical unit pressure, and are designated by percentages of the average pressure applied to the ballast by the ties. In this case it will be noticed that the maximum intensity occurs below the ties.

If the load on the soil is released we would naturally expect the compressed soil to expand, if it acts as an elastic solid. This is actually what happens. It is a well-known fact that piles will rebound slightly after the load has been removed, due to the expanding soil forcing them up. Also, piles that have withstood a certain test load will often settle under a much smaller load afterwards applied. This is because the bulb of pressure breaks down to some extent after the soil has expanded and further penetration of the soil is necessary to form a new bulb of pressure at a lower level. In underpinning operations by the standard method of concrete-filled pipes driven by hydraulic pressure there is always some slight settlement due to this rebound.

Several interesting tests were carried out by Mr. Greathead on the rebound of piles used for underpinning heavy buildings during the construction of the William Street Subway, and a description of these tests is necessary, as they were responsible for the introduction of the "Pretest" pile.

The typical method of underpinning was as follows: Around the pier foundations of the buildings to be underpinned was built a heavy grillage of I-beams and concrete, and a pit was dug between the piers and under the grillage. On the pit bottom was then placed a 2-ft. section of steel casing for a 14-in. pile, and this was jacked down by a hydraulic jack acting against the weight of the building. When driven and the earth inside removed by an orange-peel bucket or screw another 2-ft. section was added and driven down, and so on until the required depth was reached, when the next pile was similarily driven. After all the piles were driven they were filled with concrete and tested with the hydraulic jack to a load 50 per cent. greater than they would subsequently have to carry, being jacked down farther if necessary until no settlement occurred. Mr. Greathead measured the settlements and rebounds that occurred on releasing the load by means of a deflectometer. This rebound was generally about three-eighths of an inch, about half this being due to the elasticity of the pile and the other half to the expansion of the compressed soil. *Fig.* 4 shows a few of the results obtained. The rebound is clearly seen, and the subsequently greater penetration when the load was reapplied.

It was found that after the piles had been tested and the test load released there was always a settlement of about half an inch when the actual building load was carried (thirty tons to a pile). To prevent this as far as possible the contractors' engineer, Mr. L. White, introduced the system of wedging between the top of the piles and the bottom of the grillage before releasing the pressure from the jacks. At first an I-beam was placed on each side the jack and wedged up tight, but finally two jacks were used and one I-beam placed between them. By this means the rebound was kept down to about one-sixteenth of an inch, and when the load was reapplied there was no settlement up to the original test load. Since the test loads were always 50 per cent. higher than the future building load assigned to the piles it is safe to assume there will never be any further settlement.

It may be said that nothing has been mentioned to prove that these piles are not being supported by skin friction. If the steel shell, after being driven, were excavated from within down to the bottom it would be supported by skin friction alone, and the relation of the load required to sink it to the load required to sink a filled shell of the same depth would give the proportion of the load carried by skin friction. Experiments were made to obtain this proportion by finding the pressure required to sink a shell in which varying amounts of soil were left in the bottom. With excavation completed to the bottom of the inside of the shell a very small load was required to sink it; as more soil was left in the bottom greater loads were required, until with 2 ft. of soil almost complete end bearing was obtained owing to the arch action of the soil and the pile shell would support a load of 30 tons. From the data obtained it was found that only 5 to 15 per cent. of the load on the pile was supported by skin friction. Some of the curves obtained are shown in *Fig.* 5.

Still greater evidence of the small value of skin friction is obtained from the fact that excavation can be carried on alongside the pile almost to the bottom. In the underpinning of a twenty-story building one row of piles was almost entirely exposed for nearly their full length, showing that their bearing power did not rely on skin friction. On looking at the bulb of pressure diagram we can see how excavation can be carried nearly to the foot of the pile without affecting the soil under pressure, and hence the bearing value of the pile. This knowledge is of great use when designing the foundations of buildings adjacent to existing structures.

From the results of all these experiments on the vertical transmission of

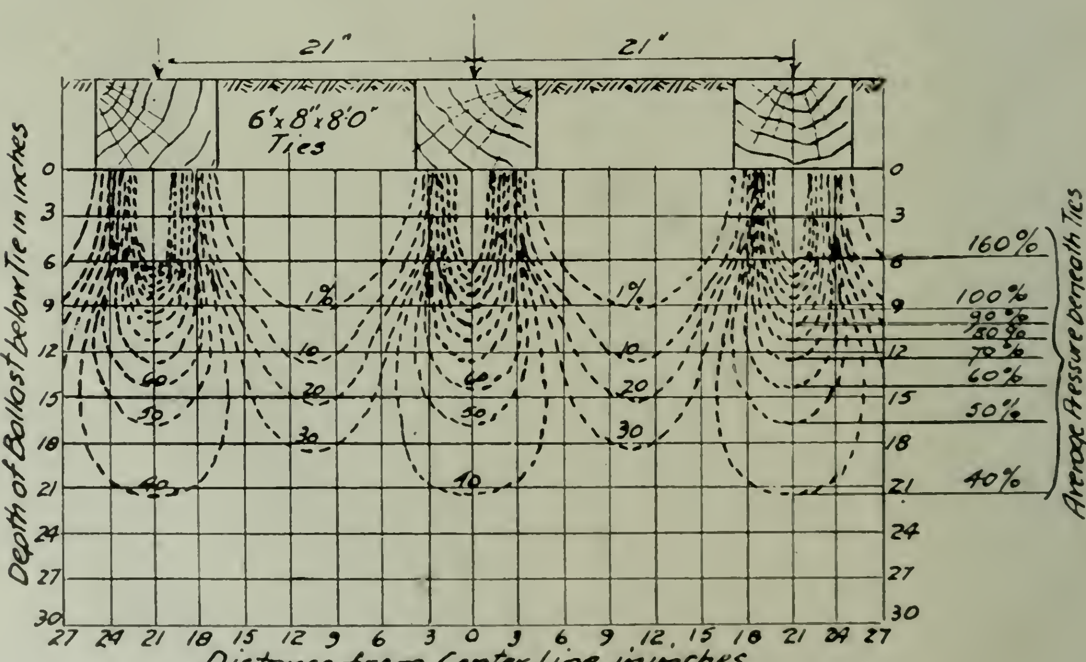


FIG. 3. "Bulbs of Pressure" under Loaded Railroad Ties

pressure through soils and on the rebound of piles, and the great success obtained in the underpinning of the heavy buildings in William Street, it was seen that the same methods could be used in the construction of new buildings, and the "Pretest" pile method of foundations was introduced. The first new building erected by this method was a twenty-two-story office building in New York, commenced in 1916 and built on fine water-bearing sand. Since this many other new buildings have been completed in New York under this system with success, the "Hide and Leather" Building (*Fig.* 6) being one of the most notable examples. It was adopted for this building not only because of economy and the great saving in time but also because it was thought that this system would give the safest foundation and the least settlement on the very poor soil underlying the building.

The method of building the foundations for a new building is essentially the same as that adopted for underpinning old buildings, with the added advantage that the design of the foundations for piers and walls can be adapted to underpinning requirements, so that much of the cost of ordinary underpinning can be eliminated. In new work, of course, the rate of driving the piles depends upon the speed with which the building is erected, since the piles are driven against the reaction of the weight of the building and do not reach their final position until the frame of the building is completed. The method of driving the piles under the "Hide and Leather" Building was fully explained in the June number, so will not be repeated here. During the driving of the piles there will be some eccentricity of loading, although the piles are driven so as to reduce this eccentricity as far as possible. For this reason the foundation walls are reinforced as continuous beams and the interior columns are connected by continuous footings.

The advantages of this system of "Pretest" foundations for heavy buildings to be erected on bad foundation soils are very apparent. As the foundations are erected simultaneously with the building the time usually required for them is eliminated, an important point when large sums are invested. Since every pile is tested with an overload, measured by a pressure gauge, and this load is not released until the pile receives its actual building load, it is certain that each part of the foundations is doing its share of the work and that no appreciable

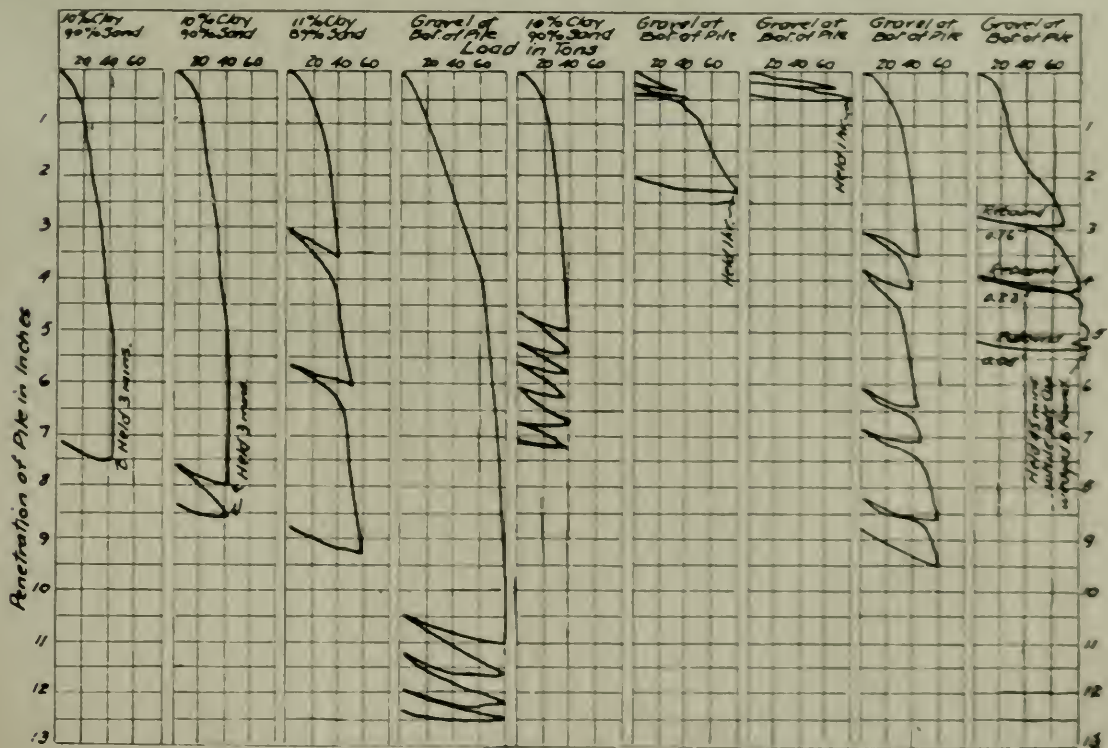


FIG. 4. Tests on Penetration and Rebound of Concreted 14" Steel Piles

FIG. 6. TESTING "PRETEST" PILES UNDER EXTERIOR WALLS.

[Note hydraulic rams and I-beams wedged between top of piles and bottom of wall footing; some of these I-beams are shown covered in.]

settlement can take place. As " Pretest " cylinders can be installed touching the property line, they can be built concentric with the columns, avoiding the use of cantilever and eccentrically-loaded footings, and often doing away with the necessity for underpinning adjoining buildings, at a great saving in cost. The credit for developing this system of foundations is due to the firm of Spencer, White & Prentiss (Inc.), of New York, by whom it is patented. The results of tests on piles used for underpinning were published by Mr. Greathead in the *Public Service Record*, an organ of the Public Service Commission of New York. An account of the experiments on the transmission of vertical pressure through soils and the curves of pressure are given in a bulletin published by Pennsylvania State College.

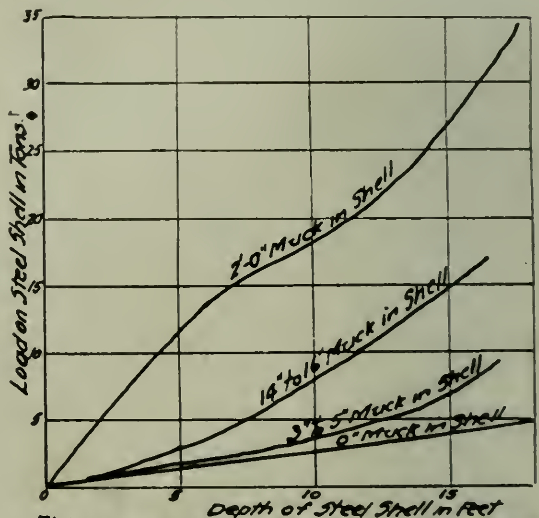


FIG. 5. Curves showing proportion of Bearing Power of Steel Shells due to Skin Friction and End Bearing. 0" Muck indicates Skin Friction acting alone; 2'0" Muck indicates almost full End Bearing.

Archibald Dawnay Scholarships, 1922.

IN accordance with the terms of the will of the late Sir Archibald Dawnay, the Royal Institute of British Architects has awarded, for the first time, two scholarships, each of £50 per annum for two years, to Mr. E. U. Channon (Architectural Association), and Mr. D. J. A. Ross (Robert Gordon's Technical College, Aberdeen), and one scholarship of £25 per annum for two years to Mr. C. S. White (Architectural Association). The scholarships are intended to foster the advanced study of construction and the improvement generally of constructional methods and materials and their influence on design.

REINFORCED CONCRETE AND FIRE-RESISTANCE.

II—EFFECT OF TEMPERATURE ON STRENGTH OF STEEL.

By J. SINGLETON-GREEN, B.Sc. (Hons. Eng.), A.M.C.I., M.Am.C.I.

It has been known for some time that when the temperature of steel is raised its strength increases and then decreases. This fact is of primary importance when considering the fire-resisting capacity of structural members composed partly or wholly of steel. Professor F. C. Lea, O.B.E., D.Sc., emphasised this point in a paper read before Section "G" of the British Association at its meeting in 1920.

On being requested to serve on the British Fire Prevention Committee Professor Lea said it seemed perfectly clear that it was desirable to consider under what conditions reinforced concrete would be sure to fail when exposed to fire, and the immediate answer seemed to be "whenever the steel reached such a temperature that its yield point was less than the stress to which the steel was subjected when the beams and slabs were carrying the loads for which they were designed." That is, if the reinforced concrete beams and slabs of a building were designed to have a working stress in the steel of, say, 7 tons per sq. in., then if during a fire the steel could by any means reach a temperature at which the yield point was less than this the floors would be bound to collapse. What this temperature would be could be found by a laboratory experiment. This data having been obtained the next step would appear to be the determination, if possible, of those kinds of concrete which would stand much higher temperatures than this and which would give a sufficient thickness of coating to the steel to prevent the steel under the conditions of a vigorous fire from reaching this temperature.

This decrease in the strength of steel with increase of temperature is noted by Professor J. B. Johnson (U.S.A.), who states in his *Materials of Construction* that the working strength of steel decreases with a rise in temperature, and that this decrease takes place at the rate of approximately 4 per cent. for each 100 deg. F. increase. Using these figures as a basis of calculation, Mr. T. D. Mylrea, in his report* on the fire at the Quaker Oats Company's premises at Peterboro, Ontario, in 1916, reckons that the strength of the slab rods would be reduced by about 80 per cent. This is rather an alarming figure, and emphasises the need for more definite information on the subject. This has been supplied to a certain extent by the experiments of Professor Lea, the results of which are given in brief below:

TESTS BY PROFESSOR F. C. LEA.†

TENSILE TESTS ON MILD STEEL.

Mild-steel specimens were prepared from ⅞-in. diameter bar, which had the following composition:—

	Per cent.
Carbon	0·090
Silicon	0·010
Sulphur	0·164
Phosphorus	0·111
Manganese	0·573

Screwed specimens, ¼ in. diameter and 2½ in. long in the parallel part, were prepared. The figure shows the results obtained from tests of mild steel which had actually been supplied for reinforced concrete. The curves show clearly what happens, and several points are worthy of note.

Breaking strength at 0 deg. C. = 30 tons/sq. in.
Maximum strength occurs at about 235 deg. C.
" " = 43 tons/sq. in.

Beyond 300 deg. C. the strength diminishes very rapidly, and at a temperature of from 615 deg. C. to 640 deg. C. the breaking strength is less than 7 tons/sq. in. The actual temperature (within narrow limits) at which the fracture takes place at this stress (7 tons/sq. in.) depends upon a time factor of heating and loading. For instance, points lying on the curves were obtained by bringing the specimen to a steady temperature, maintaining it at this temperature for 20 minutes, and then breaking. On the other hand, two coinciding points at "A" (*see* Fig.) were obtained by loading bars with a

* B.F.P.C. "Red Book," No. 225.

† *Proc. Inst. C.E.*, Vol. ccix., 1919-20, Pt. 1, page 304.

stress of 15,900 lb. (7·1 tons) per sq. in. and gradually raising the temperature of the specimens until they broke. It will be noticed that the points "A" lie very close to the curves.

It may be pointed out, however, that the yield stress is the one which should be used when considering the factor of safety, and that the danger point will be reached when the yield stress, and not the breaking stress, reaches 7 tons per sq. in. It is interesting to note, therefore, that at the dangerous temperature (600 deg. C. to 650 deg. C.) the curves of breaking stress and yield stress practically coincide, implying that fracture occurs immediately after yielding. For all practical purposes, then, in the question of fire-resistance we can take it that both the yield stress and the breaking stress reach the value of 7 tons per sq. in. at a temperature of 600 deg. C. to 650 deg. C.

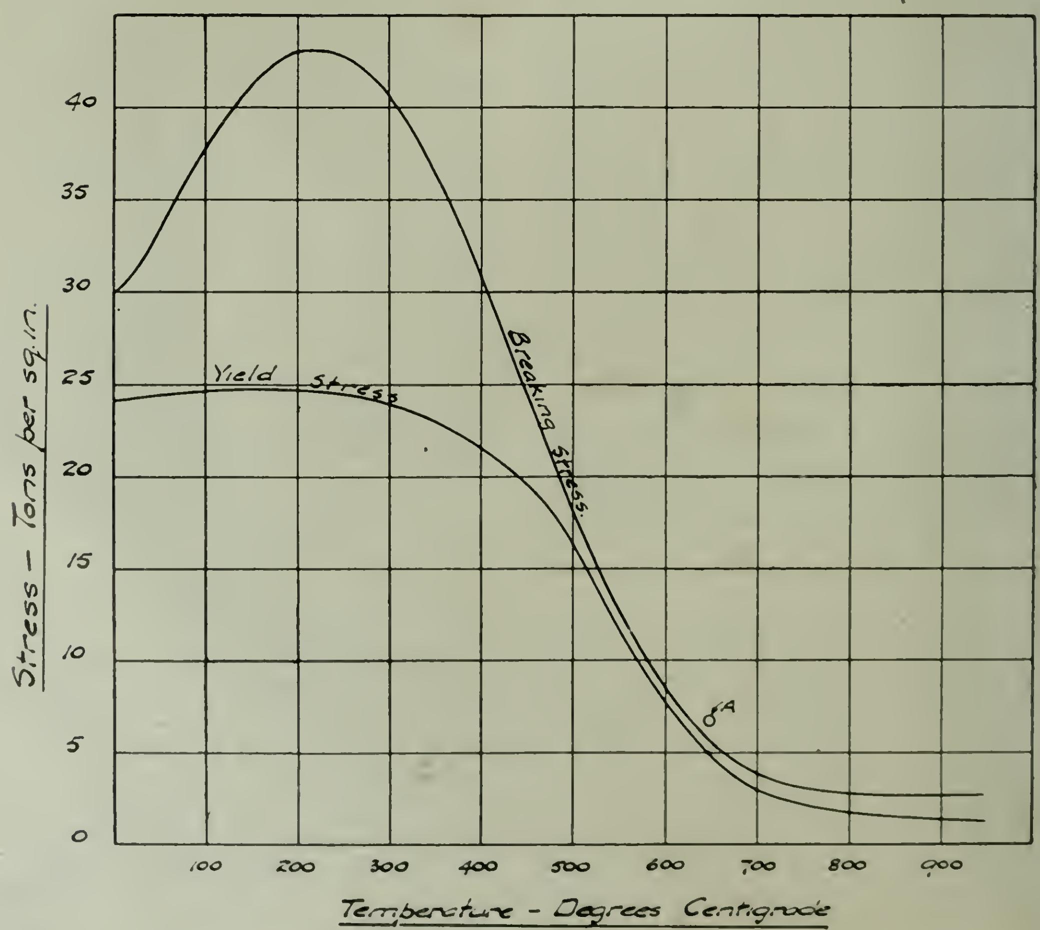
Tensile Tests on High-Carbon Steel Wires.

The effect of temperature above 450 deg. C. is very marked in these high-carbon steel wires. At a temperature of 475 deg. C. wire containing 0·9 per cent. carbon stretched continuously when it was loaded simply with the fittings necessary to connect it with the machine. The stress in those circumstances was certainly less than 7 tons per sq. in. It was clear from this test that the elastic limit and the so-called yield point were well below 7 tons per sq. in.

Conclusions.

It is noticeable that these results are hardly in agreement with the statement of Professor J. B. Johnson that the decrease in strength of steel is approximately 4 per cent. for each 100 deg. F. increase. For instance, suppose we take 32 deg. F. as

BREAKING AND YIELD STRESSES OF MILD STEEL
(after Prof. F. C. Lea, O.B.E., D.Sc.)



the normal temperature; then for a decrease of 75 per cent. (to bring the factor of safety of 4 to unity) the increase necessary is 1875 deg. F., thus causing a temperature of 1907 deg. F. This temperature of 1907 deg. F. corresponds to 1042 deg. C.

In Professor Lea's tests on mild steel it is found that both the yield stress and the breaking stress of the steel reach the design working stress of 7 tons per sq. in. at a temperature very little more than 600 deg. C., and there seems no doubt that if the beams and slabs are fully loaded failure is bound to take place when the steel reaches a temperature approximating to 650 deg. C. It is probable, then, that the slab rods in the Quaker Oats fire were even in a worse condition than that assumed by Mr. Mylrea in his report.

It is interesting to note that in the discussion following the presentation of Mr. R. L. Humphrey's paper to the Concrete Institute in October, 1911, Mr. E. F. Etchells took a very serious view of this decrease in the strength of steel. He said, "Suppose a building be designed with the safety factor of 4, the calculated working stress being, therefore, one-fourth of the ultimate. The secondary stresses, which may not appear in the calculation at all, may be as high as 100 per cent. of the nominal working stress. You have, therefore, the actual stress equal to about half the ultimate, and then as soon as we mount to the increased temperature where the ultimate strength is reduced by half there is disaster at once." In the author's opinion, however, this is rather an extreme case, and we shall be well on the way to safety if we can keep the steel temperature below 600 deg. C. and at the same time allow for as many secondary stresses as possible in the design.

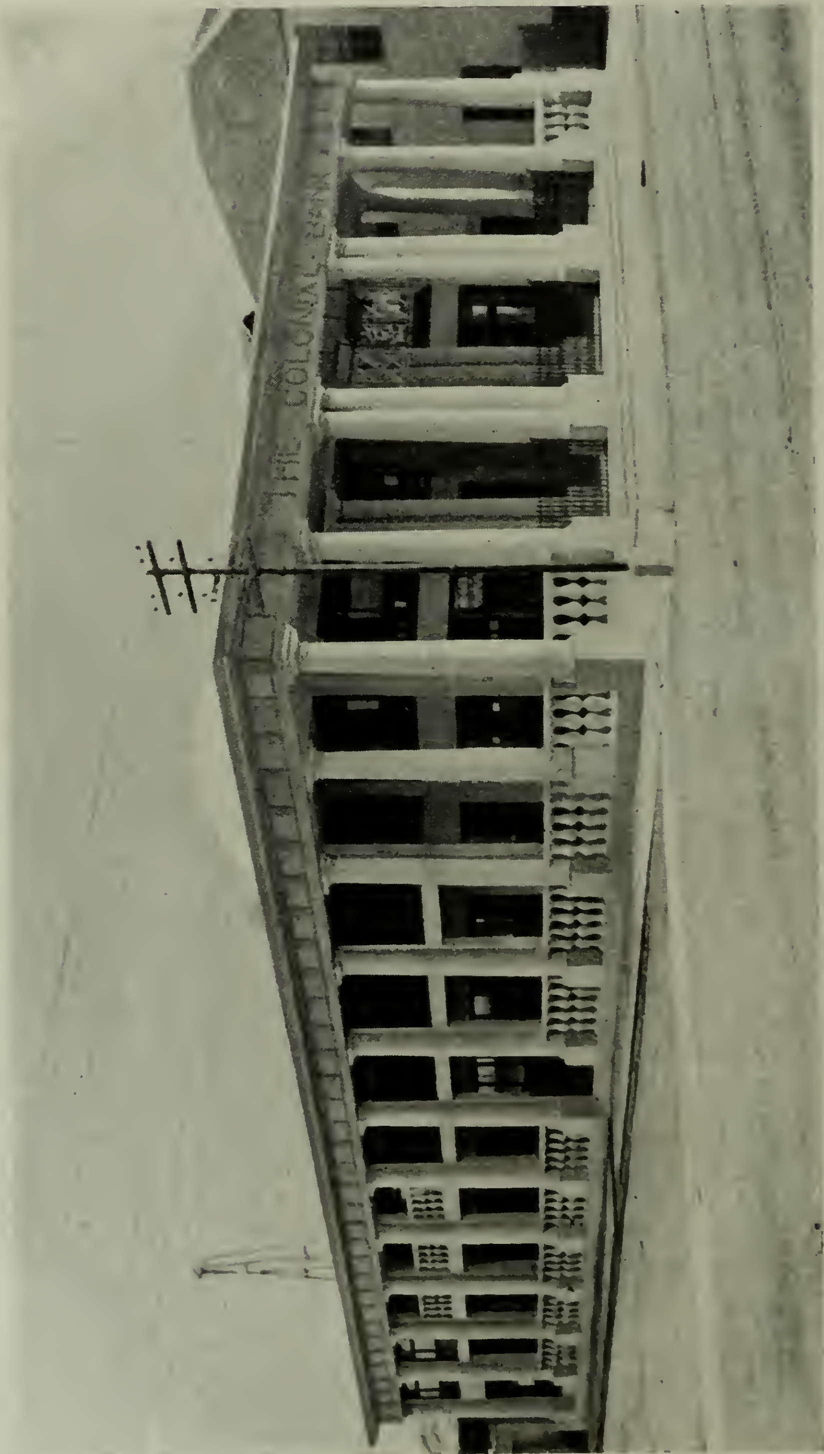
If some of the alloy steels ever become cheap enough and can be used for reinforced concrete slightly higher temperatures may be allowable without risk of failure, but then advantage could not be taken of the high breaking strength of these alloys at ordinary temperatures if the failing stress under temperature is still to be 7 tons per sq. in. We may take it, then, that as far as the steel is concerned the tests clearly indicate that its temperature must be kept below 600 deg. C.

This, then, is a fundamental fact of importance in considering this question of fire prevention. If the concrete covering is too thin, or if it cracks and fritters under the temperature to which it is exposed, then the steel must quickly reach the dangerous temperature. On the other hand, if the steel can be kept below this dangerous temperature for a certain length of time, during which the worst part of the fire may have spent itself, then the building is likely to survive. The following question then automatically presents itself: Is it possible to obtain a covering for beams, slabs and columns that will not readily crack, and is such a bad conductor that it will prevent the steel from reaching the dangerous temperature; or, alternatively, can other means be found for keeping the reinforcement cool in case of fire?

MODERN RESEARCH.

During the years of the war organised experiments* were carried out in Pittsburg by the United States Bureau of Standards, in London by the British Fire Prevention Committee, and in Berlin by the German Society for Testing Materials. The American tests dealt with reinforced concrete columns; the British with plain and reinforced concrete floor slabs; and the German with specially-built buildings in which a number of different types of materials were incorporated. Almost simultaneously in three countries the need for more definite knowledge of the capacity of different materials to withstand the temperatures of severe conflagrations crystallised into a systematic programme of research. In each case the programme has already been carried out to a first interval, during which the reports of work accomplished may be digested, comparisons made, and deductions drawn. The results of these tests will be considered in subsequent articles, but first it will be necessary to get a good grasp of the behaviour of minerals and aggregates when subjected to heating and cooling such as would occur in a fire.

* See *Concrete and Constructional Engineering*, March, 1920.



[Messrs. Stanley Barrett & Driver, Architects.

THE COLONIAL BANK, GEORGETOWN, DEMERARA. (See p. 649.)

THE COLONIAL BANK, GEORGETOWN, DEMERARA.

THE new premises for The Colonial Bank at Georgetown, Demerara, have now been completed by Messrs. S. Pearson & Son (Contracting Department), Ltd., London, from the design of Mr. Stanley Barrett, F.S.Arc., of Messrs. Stanley Barrett and Driver, architects, of Lower Seymour Street, London. The design is classic, based on the Doric order of the Temple of Marcellus, Rome, and all unnecessary ornament has been avoided.

The building has a frontage of 62 ft. 6 in. and a return of 122 ft. 9 in. Doric columns, 20 ft. high, support a massive classic entablature and cornice, forming a wide open colonnade the whole length of the elevations. The colonnade is raised 18 in. above the pavement level, and is approached by wide marble steps in the centre of the front elevation, where the main entrance doors are situated.

The roof is flat, with a slight fall from the centre to the side gutters, which are concealed from view and formed in the surface of the concrete above the cornice. Upon the roof over the banking hall is a reinforced concrete dome 34 ft. 6 in. in diameter, in which are eight dormer openings, six of which are glazed to allow light to be reflected downwards from the spherical surface of the dome while the other two openings are fitted with powerful exhaust fans.

The construction is notable for its simplicity, and consists of piers and columns evenly spaced to support the floors and roof, the spaces being filled with glazed and louvred windows and doors which allow a free passage of air in all directions.

The whole front portion of the building is occupied with the large banking hall, over 50 ft. wide by 70 ft. long, and 32 ft. high from floor to dome. Around the banking hall is a wide octagonal gallery supported by Doric columns, around the edge of which is a classic balustrade.

The foundations consist of a raft of concrete resting on and associated with a system of concrete beams over the entire area and strongly reinforced with steel bars. Upon this raft the superstructure of the building has been framed and moulded in concrete. Every column, beam, floor, and roof slab has its steel reinforcement hooked or tied in with its neighbouring unit, so that the whole fabric is practically a network of steel rods surrounded by concrete, which allows of the column and beam units being fabricated in advance and placed in position as the construction advances.

The surfaces of the concrete within the building have been distempered white, except the walls and pilasters, which are pale green. A narrow skirting in dull black has been run around the whole of the walls inside, and adds to the finish of the work.

[*Messrs. Stanley Barrett & Driver, Architects.*

THE COLONIAL BANK, GEORGETOWN, DEMERARA: FRONT ELEVATION.

[*Messrs. Stanley Barrett & Driver, Architects.*

THE COLONIAL BANK, GEORGETOWN, DEMERARA: INTERIOR.

The floors are paved with 1-in. terrazzo marble tiles in the colonnades and public spaces, and 2-in. pitch pine and English oak blocks in the administrative offices and banking hall. The latter form of block flooring is laid in "basket" pattern with metal tongues on a surface of hot bitumen over a waterproofed cement under-base. This form of construction eliminates any possibility of damp arising and lifting the floor. Special attention has been paid to the joinery, which has been carried out in brownheart, a hard-wood from Dutch Guiana weighing about 66 lb. per cu. ft.

The dimensions of the building are: length, 122 ft. 9 in.; breadth, 62 ft. 6 in.; height, pavement to cornice, 24 ft. 4 in.; pavement to top of dome, 34 ft. 3½ in. The materials used were: crushed granite, 1,100 tons; river sand, 680 tons; Portland cement, 350 tons; steel reinforcement, 45 tons.

The constructional steelwork in the coat-of-arms, grille, and Bostwick gates has been supplied by Messrs. Galsworthy, Ltd., London. The electric fittings, all in bronze, have also been supplied by Messrs. Galsworthy, Ltd.

The building has been constructed throughout in reinforced concrete on the "Coignet" system, to the detail drawings of Messrs. Edmond Coignet, Ltd., 125, Gower Street, W.C.1.

During the construction of the building the interests of the Colonial Bank have been looked after by their Engineer, Mr. Cecil J. Allen, whilst the contractors were represented by their Engineer, Mr. R. F. Ward-James, with Mr. J. L. B. Morris as accountant and cashier, and Mr. H. A. Amo as foreman in charge.

The Preservation of Ancient Monuments.

FURTHER to the recent controversy as to the repair of Tintern Abbey with the aid of reinforced concrete, it is interesting to note that Sir Francis Fox and Sir Charles Nicholson, Bart. (Cathedral Architect), have recommended that the cracks which have existed in the north-west tower of Lincoln Cathedral for many years should be filled with cement grout, and this work is now being carried out. Similar methods have been adopted for strengthening the fabric of Winchester Cathedral and other historic buildings.

CONCRETE IN ARCHITECTURE.

(Contributed.)

ARCHITECTURALLY considered, there is no limit to the scope of fine concrete in almost every type of building, however humble or monumental. For one reason it is considerably less costly than stone, and not more expensive, when economically designed, than good plaster, the cost of which for exterior work, usually carried out under somewhat trying conditions, makes it laborious and expensive. This outstanding fact allows of the introduction of architectural enrichment without too considered a regard for the cost. But it has, of course, to be of the best. Pre-cast concrete when manufactured for architectural detail must be of a very high grade, both as regards material and workmanship ; while the setting of the pieces to obtain the best results should be in the care of workmen used to handling the best kinds of stonework.

There is a vast difference, however, in the constructional detail of stone and pre-cast concrete, for inasmuch as the former has to be cut from heavy blocks and to heavy sections those of concrete may be considerably lighter—the lighter

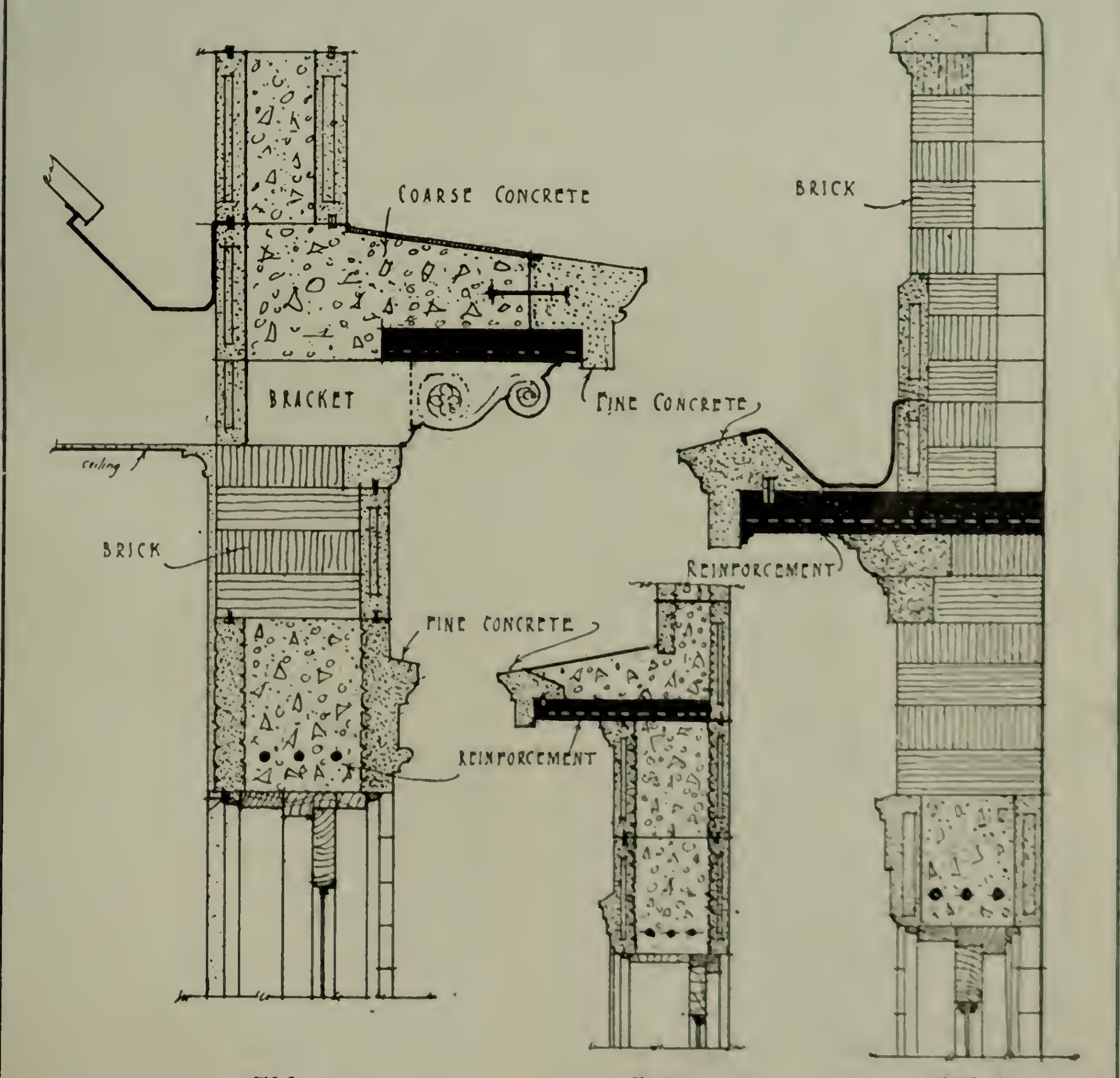


FIG. 1. FIG. 2. FIG. 3.

the better—facilitating handling and easing the loads on projecting structures. Thus a classic concrete cornice, unusually massive in appearance, is, in reality, a light though thoroughly substantial structure, as will be seen from the drawings, which illustrate entablatures of varying depths and projections. The resulting effect produces absolute homogeneity and solidity of appearance, even though the cornice may be of the lightest construction, as in the case of *Fig.* 3, where it is employed as a gutter for the draining of rainwater.

The thickness of some of the members, especially the bands and arch facings, may be reduced down to two inches. Every reduction means a saving in cost all round, including material, moulds, manufacture, and setting. The heaviest pieces should not weigh more than 50 lb., while the smaller members may be as light as 20 to 25 lb. Bands should conform to brick dimensions in height, and be held back on the brickwork with non-corrodible metal ties. Profiles should be cast against seasoned hardwood or cast-iron shapes. Mitres should not be used, all intersections being cast in one piece, as also those that are returned mitred and stopped.

With light sections everywhere the cutting of moulded pieces to form closers is quickly and easily accomplished. Considerable projection may be obtained in cornices by using reinforced cantilevered slabs, the whole light mass being kept within the centre of gravity sufficient for complete safety during erection, and regardless of the subsequent superincumbent load of parapet and coping.

It would be no exaggeration to say that the net cubical content of any of these sections is less than half that of stone, which factor in itself cuts the price in half. The actual mixture may be finely cast to any required profile, ready for use, at a cost less than that of the cheapest stone in random blocks from the quarry before any tooling has been commenced on it.

With the savings effected in erection (no heavy lifting gear being required) it is safe to say that concrete used architecturally is from one-quarter to one-sixth the cost of stone, while its lasting qualities are much greater. In this respect, although it will take on and reflect age in the same way as will stone, it will never perish in all the ages to come.

Cast concrete used architecturally should be composed of light-coloured aggregates and cements, no colouring ingredient whatever being used, especially for exposed work. The addition of colours is not only unnecessary, and sometimes injurious, but it lays concrete open to being called "artificial stone." In reality it is less artificial than any other wall-building material, not excluding brick and terra-cotta, which are the mechanical products of baked clays; while concrete of the kind described is a natural conglomerate of stone and cement.

Indeed, the best natural stone colour effects are those obtained by using the chippings and screenings of Portland, granite and other stones themselves as they come from the quarries or stone yards, knitting them together with cements of a natural light tone so that their colour characteristics may not be destroyed. The resulting effect, as it is natural to expect, is exactly that of stone without recourse to any artificial effort. The stone colour is in fact exactly reproduced. Similarly the texture (using the rodding process and well-screened grains of aggregate) is as fine and close as that of stone, from which it is almost impossible to dissociate it, coming as it does out of the inmost nature of the materials themselves. The temptation to colour concrete mixtures in imitation of various stones of distinctive colour has unfortunately earned for the process a certain amount of contempt, as this colouring has usually been overdone and can seldom be relied upon on exposure to endure climatic conditions.

It may be added in conclusion that provided the various members are perfectly made—and this can easily be accomplished by using inflexible metal moulds of simple design—the ultimate result from the mechanical standpoint is much more perfect than that obtained by the best tooled stone, while each piece may be locked with a simple system of tongues and grooves, thus providing greater security and strength.

CONCRETE PRESSURE PIPES.

THE use of cement and concrete for manufacturing pipes and conduits has long been the basis for a considerable industry, both in this country and abroad, and as the field of the concrete pipe is widening, principally due to the possibilities of reinforced concrete, so numerous systems and methods of producing satisfactory pipes and tubes have been introduced, and it is possible to obtain in this material goods of this class which compete and compare very favourably with steel and cast iron.

Before describing some of the special features of one of the large establishments where the manufacturing of pipes is specialised in and carried out on a large scale, it may be useful to mention a few generalities in regard to the technical side of the construction of concrete pipes, especially those exposed to internal pressure of some magnitude.

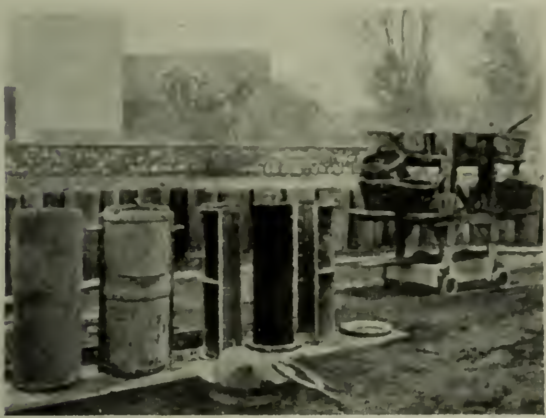


FIG. 1. MOULDS AND MANDREL.

FIG. 4. REMOVING MOULD.

The choice of materials is important, and more particularly is it necessary to employ an absolutely first-class finely-ground cement, as the concrete has to be both watertight and of high resistance to all forces likely to be met with. Further, it is desirable that the cement should be of the fairly quick-setting variety in order to liberate the moulds as soon as possible and thereby reduce the number of forms necessary for a certain output. The sand and gravel must be clean and sharp, and so graded as to produce the densest possible mixture to ensure strength and watertightness of the concrete.

The reinforcement consists of straight longitudinal bars and annular or spiral reinforcement, the function of the former being to take temperature stresses and longitudinal stresses due to variations or irregularities in the support, whereas the annular rods take the stresses from

FIG. 2. POURING.

FIG. 3. REMOVING MANDREL.

internal pressure, weight of filling, etc. The annular reinforcement should be strong enough in any case to take, when stressed to about 12,000 lb. per sq. in., the whole of the tension due to internal pressure without any help from the concrete, but at the same time the thickness of the concrete should not be less than would give a maximum tensile stress of about 100–150 lb. per sq. in. in the concrete if the latter alone were to resist the tension. In the course of some experiments carried out under the writer's supervision on concrete tubes reinforced according to these principles it was found that they remained watertight up to the calculated limit, and on increasing the pressure a slight leakage began, which, however, stopped on allowing the pressure to sink back to the limit, thus showing that although fine cracks had occurred in the concrete on overstressing the steel, these cracks closed up on the steel contracting with the diminution of pressure.

While concrete pipes carrying drainage, sewage, etc., under no pressure are often made ovoid in shape, pressure pipes are always circular whether reinforced or not, this being the equilibrium stress line for uniform internal pressure. Pipes with a diameter above 2 ft. are generally reinforced whether the internal pressure necessitates it or not, as the transport of the larger size pipes would be difficult without reinforcement.

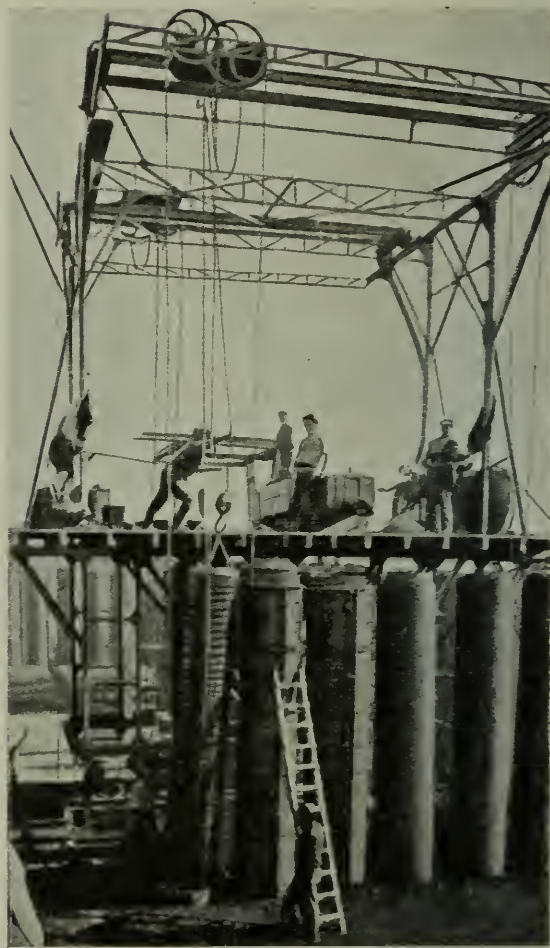


Fig. 7. Plant for Concreting and Handling Long Tubes.

In the following illustrations are shown the methods of manufacture employed in a well-known cement factory at Grenoble, the "Societe Generale & Unique des Ciments de la Porte de France," which specialises in concrete pipes. For tubes made in the yard, sheet metal forms in halves are used with an expanding mandrel, resting on and registering in an annular bottom piece. *Figs.* 1, 2, 3 and 4 show the mould, the pouring of the concrete and the removal of the mandrel and of the forms, while *Figs.* 5 and 6 show two stages in the preparation of the reinforcement, the winding of the annular reinforcement and the connecting of the latter to the longitudinal bars by wire bindings. *Fig.* 7 shows the gear for concreting and handling the mandrel and the moulds of longer tubes. Where the diameter of the tubes becomes too large for easy

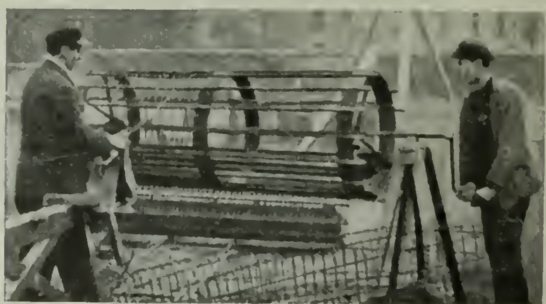


Fig. 5. Winding Annular Reinforcement.

Fig. 6. Tying Annular Reinforcement to Longitudinal Bars.

Fig. 8. Preparing Reinforcement.

Fig. 10. Concreting Outside Conduit.

transport, the concreting is done *in situ* after placing the reinforcement, as in *Figs.* 8 and 9, where the making of the latter and the internal concreting is shown in progress, while the process of external concreting is shown in *Fig.* 10. *Fig.* 11 is an example of a high-pressure main, 7 ft. in diameter and 75 miles long.

In the case of very high pressures it may be found difficult to obtain the requisite watertightness in the ordinary way, and it may be necessary to employ other means of rendering the pipe watertight, such as, for instance, a sheet steel insertion as in the "Bonna" system. According to this method an oxygen-welded steel shell ensures the watertightness and is embedded between two layers of reinforced concrete, the internal one, which is thin and lightly reinforced, having for its purpose to protect the steel shell against oxydisation, whereas the external layer is calculated and reinforced for taking the internal pressures and other forces to be dealt with. It is claimed that these tubes can be made to withstand pressures corresponding to a head of 2,000 ft. of water, and they are therefore used for pressures exceeding 200 ft., up to which latter the ordinary reinforced concrete tube is quite satisfactory.

It should perhaps be mentioned that in order to obtain a very high output with a limited number of moulds the factory at Grenoble employs a special quick-setting cement which enables the moulds to be removed from 8 to 10 minutes after pouring, so that two sets

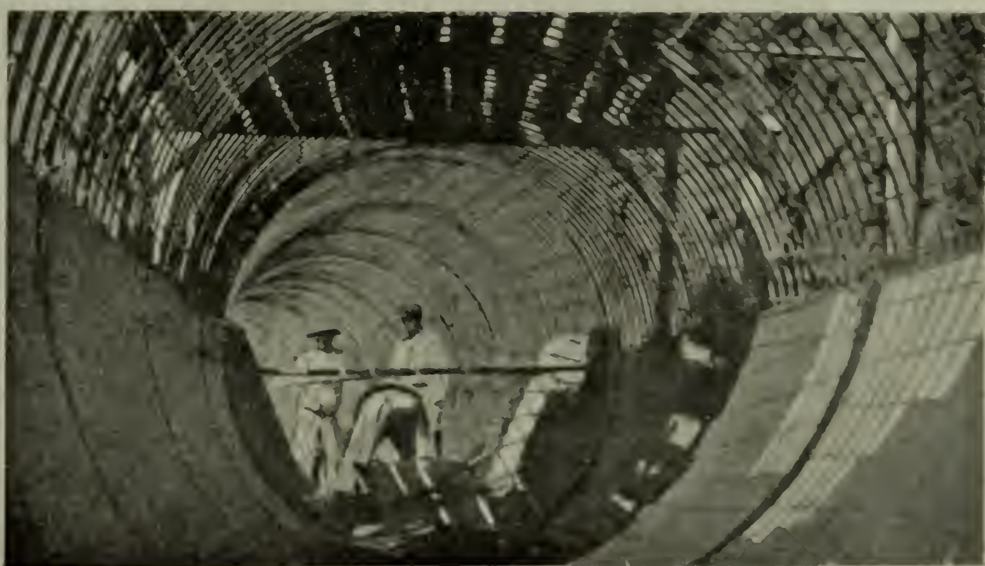


Fig. 9. Concreting Inside a Conduit of 8 ft. Diameter.

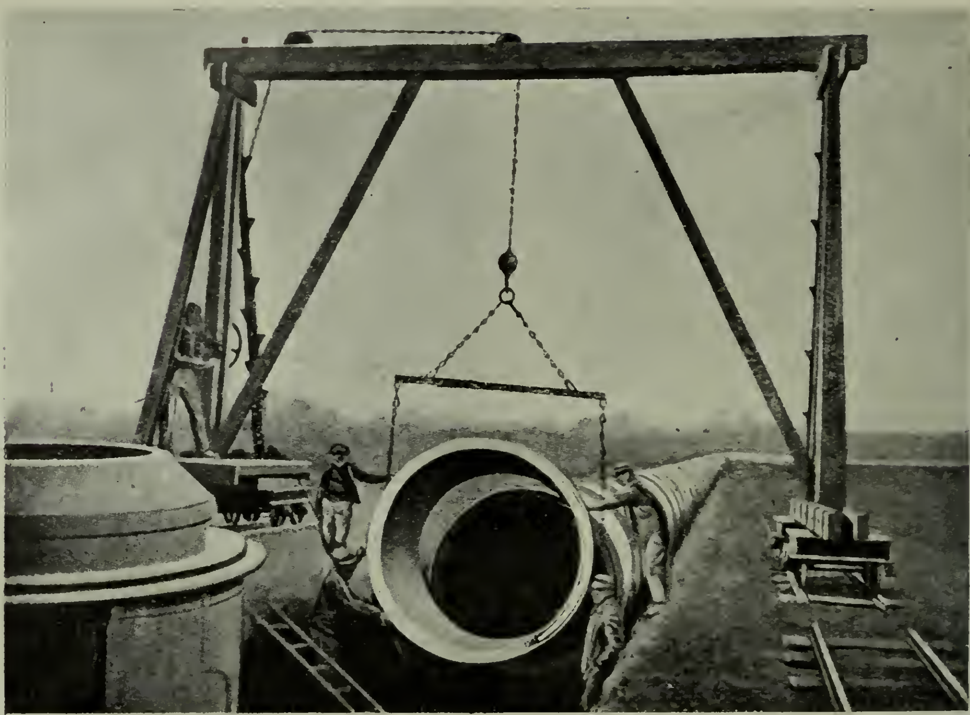


FIG. 11. HIGH-PRESSURE MAIN: 75 MILES LONG, 7 FT. DIAMETER.

of moulds worked continuously with two men can produce fifty tubes per day; the mixing and pouring must, of course, be done very quickly to guard against too early setting, and it is claimed that the tubes thus produced can be transported safely from three to twelve hours after moulding, according to size.—R. N. S.

KAMANASSIE DAM, THIRD LIFT PROCEEDING (November 16, 1921). (See p. 658.)

IRRIGATION WORKS IN SOUTH AFRICA.

We illustrate herewith three dams which are being built by the Irrigation Department of the Union of South Africa in connection with an extensive system of works for the regulation of the available water in South Africa.

The Hartebeestpoort Dam.—This dam is being built about 25 miles from Pretoria for the conservation of irrigation water, and will feed two canals approximately 30 miles long, one on each bank of the river. The dam is of the constant-angle arch type and will have a total height of 198 ft. above lowest foundation where it is 72 ft. thick ; the depth from bedrock to river-bed level varies from 25 to 35 ft. The width of the Poort at river level is 150 ft., but the crest length of the dam will be 450 ft., with a width of 15 ft. over which a main road will pass. At the crest the radius of the arch is 225 ft. to the downstream face. On the left flank a trough spillway, 125 ft. wide on the line of the dam and 415 ft. long, is being excavated to deal with the maximum probable flood ; the spillway will be bridged to carry the main road from the dam.

Work was commenced in 1918. To enable the work of placing the foundations to be accomplished in the dry, two curved concrete coffer dams were started. After the upstream dam was completed by divers, it was discovered that solid rock had not been reached. The downstream coffer dam was, therefore, carried down to boulders only. A second diversion rock-fill weir was built above the upper concrete diversion dam. It was decided to tunnel through the right bank and completely divert the river through the tunnel. The tunnel, which is 240 ft. long, 12 ft. wide, and 6 ft. deep, with a grade of 1 in 200, was worked from both ends, the headings meeting after six weeks. The river is led into the tunnel from the rock-fill diversion weir by a short concrete approach flume also 12 ft. by 6 ft., and at the outlet another short length of concrete flume delivers the water into a corrugated iron flume, supported on timber piles, which takes the water clear of the site.

The construction of the diversion weir was commenced early in May, 1921, when the tunnel and most of the inlet and outlet fluming was almost complete. Some 9 in. by 3 in. deals were driven into the sand and gravel to form close piling, which was backed by rock-fill and faced with a clay blanket which was carried 60 ft. upstream along the river bed to reduce seepage. A 5-ton crane was erected on each bank to command the greater portion of the excavation. Grabs of $\frac{3}{4}$ cu. yd. capacity were used with these cranes for a time, but the cranes would not stand up to the heavy work and a graded wire-rope haulage which

Hartebeestpoort Dam (September 8, 1921).

was installed subsequently successfully dealt with the 8,000 cu. yds. of material which was removed.

On July 29 work was sufficiently advanced to commence placing concrete. The concrete mixing plant was in two complete units, each consisting of rock, sand, and cement bins from which the materials ran through gates into adjustable measuring boxes, from which they passed to the mixer through a chute. The gates from the measuring boxes to the chute were operated by compressed air. As the materials passed into the mixer, of 1 cu. yd. capacity, a measured quantity of water was added. The mixers tipped direct into 1 cu. yd. capacity "cocopans," which were hand trammed to the wall. All the concrete was placed by the two 5-ton cranes, which lifted the pans off their frames and tipped them into the wall. The whole of the concreting plant was designed on the works.

On September 7 a total of 9,500 cu. yds. had been placed in the dam, and the whole wall was 6 ft. above river-bed level.

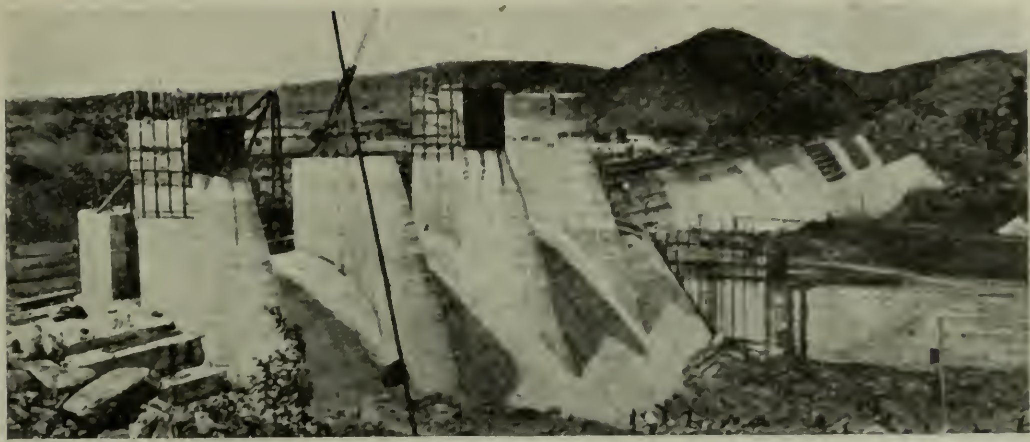
Kamanassie Dam.—Part of the conservation works in the Oudtshoorn District, this dam is of gravity section, 1,265 ft. in length, with a maximum height of 145 ft. from foundation to crest. The width of the wall at river-bed level is 84 ft., and the thickness at the top will be 8 ft. The main spillway will be on the right flank, and will be 300 ft. wide with a waste weir wall 600 ft. long. There will be an emergency spillway on the left flank with a waste weir 300 ft. in length discharging into a channel 150 ft. wide. The estimated quantity of concrete required is 160,000 cu. yds.

Work on the Kamanassie Dam was commenced early in June, 1919, and at the end of November, 1921, 57,000 cu. yds. of concrete had been placed.

Stone for crushers was quarried in the main spillway channel and run in side-tipping trucks to a reinforced concrete platform over crushers of sizes 24 in. by 19 in. and 16 in. by $9\frac{1}{2}$ in. The crushed stone then fell into gable-end hopper wagons which were run out on gantries and emptied, either into the bins of the mixer station or over the tunnel bin for reserve stone. Sand was delivered to bins in side-tipping trucks, and cement was run out on platform wagons and bags emptied into the bins. The mixer station contained two $\frac{3}{4}$ cu. yd. "Ransome" mixers, and the cement, sand, and stone were fed into these through gates operated by hand. The outlets of the cement bins were fitted with adjustable measuring boxes, whilst the quantity of sand and stone was gauged in the charging hopper of the mixers. Water was measured in automatic tanks. The mixers discharged into hopper trucks for running out on the gantry or into skips for transport by the cableway.

The foundation in the right half of the river bed was first excavated inside a coffer dam and the flow of the river confined to a width of 200 ft. near the left

Hartebeestpoort Dam, looking Downstream (February 2, 1922).



Lake Mentz Dam (February 10, 1922).

abutment. A cut-off trench was carried down to a greater depth than the normal foundation, and by May 6, 1920, this was sufficiently far advanced to permit concrete being placed. This was commenced by two mixers working in the foundation. By September 2, 1920, the foundation of the right half of the river bed was sufficiently advanced to permit of the diversion of the river to flow over the concrete, and to allow the left half being enclosed by coffer dams. At this date a start had been made with the next lift of the dam wall by erecting two 5-ton locomotive cranes on the right flank about 20 ft. above the river level. This lift was carried forward by running concrete from the mixer station on a gantry and the two cranes placing plums and gradually travelling towards the centre of the river. After an interruption due to a flood, the second lift reached the left abutment at the end of October, and early in November the two cranes were raised another 20 ft. and then travelled back to the right flank on the third lift. Arrangements were then made to erect an intermediate tower on the wall above No. 2 Outlet and by this to raise the cable way to a sufficient height to complete the wall up to crest level. Whilst the middle of the dam was being built up with concrete transported by the cableway the flanks were built by mixer stations erected near the crest level and the concrete run out in hopper trucks along the top of the wall.

Lake Mentz Dam.—This is a gravity-section concrete dam. The total height from the lowest foundation is 113 ft., and from the river bed 94 ft. The maximum bottom width is 83 ft., and the top width 8 ft. The total length along the crest is 1,220 ft. The total amount of concrete required is estimated at 168,000 cu. yds. The concrete used in this dam is in the proportion of 1 : 5 : 10. It is stated that this mix is quite good for the purpose of filling in a gravity dam. The concrete is mixed rather wet, and left in the batch mixer for 2½ minutes. It is protected by a facing of from 3 ft. to 5 ft. thick of 1 : 3 : 6 mix composed of quartzite rock and crushed quartzite sand. Tests on the 1 : 5 : 10 concrete gave crushing stresses of between 200,000 and 150,000 lb. per sq. ft. at six months, and between 150,000 and 75,000 lb. per sq. ft. at three months. The average weight is between 141 and 142 lb. per cu. ft.

The information given above and the accompanying illustrations are given by the courtesy of the *South African Irrigation Department Magazine*.

NEW HARBOUR WORKS AT VANCOUVER, BRITISH COLUMBIA.

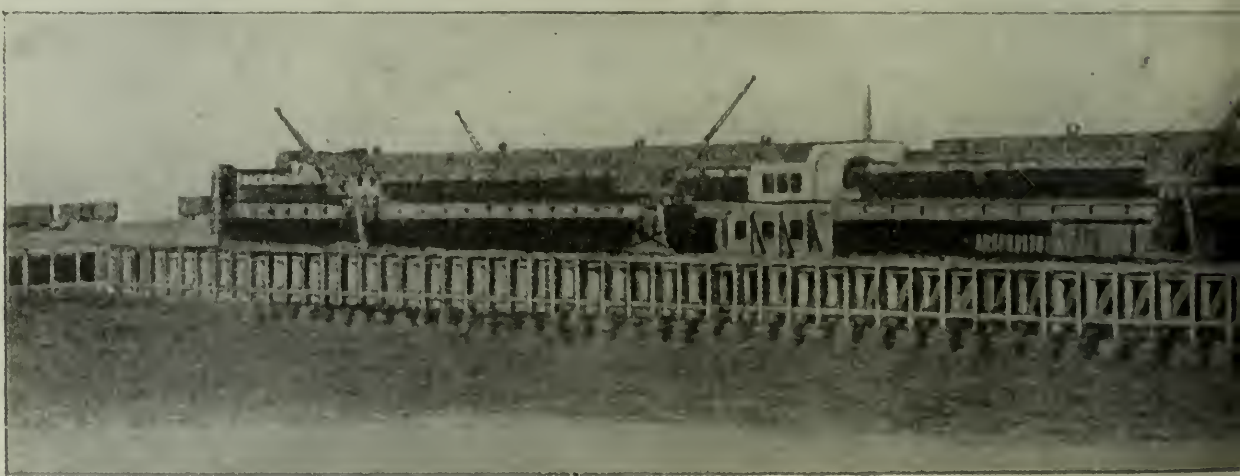
Contracts were let last year and construction commenced on the first unit of the new harbour development for the Harbour Commissioners of Vancouver, B.C., in accordance with plans and specifications prepared by Mr. A. D. Swan, M.Inst.C.E., Consulting Harbour Engineer, Montreal. The contractors are Messrs. Grant & MacDonald (Vancouver) for the dredging, and the Northern Construction Co. and Major-General J. W. Stewart (Vancouver) for the whole of the works of the pier and transit sheds. The new pier is situated on the main harbour front at Burrard Inlet, about 1⅜ miles from Vancouver City Post Office.

The general dimensions of the pier are approximately 1,200 ft. long by 340 ft. wide, with a shore quay about 900 ft. long by 350 ft. wide. Several alternative designs for different types of construction were prepared by the Engineer, such as concrete crib walls with cellular block foundations; the same type of wall on rubble foundations; reinforced concrete cylinder pier; reinforced concrete pile pier; solid sand and gravel embankment filling with reinforced concrete cylinders along the sides and outer end, etc., and this latter design has been adopted, as it affords a thoroughly substantial, permanent, fire-resisting structure.

The sand and gravel filling forming the heart of the pier is about 134 ft. wide at the top, and at the inner berths, where the basins are to be dredged 35 ft. below ordinary low water, there are four rows of reinforced concrete cylinders resting on solid rock and carrying pre-cast concrete trusses which support the floor or deck of the pier. At the outer berth, where there is a minimum of 45 ft. below average ordinary low water, there are three rows of reinforced concrete cylinders.

The front line of the transit sheds will be constructed about 30 ft. back from the coping line of the pier, so as to permit of two lines of railway tracks along the front of the shed, and a single rail at coping level for the cranes. Transit sheds, three of which are 500 ft. long and one 400 ft., are all of reinforced concrete, two stories in height by 110 ft. in width, with a loading platform in addition at the back of the sheds. Between the sheds along the centre line of the pier there is accommodation for three railway tracks and a roadway for cart and motor traffic. The floor of the sheds at the front is at the same level as the coping of the pier, and the ground floor of the sheds will be constructed on an easy gradient from the front to the back so as to obtain the requisite height to permit of the floor of the railway cars being at the same level as the floor of the sheds, the roadway level being practically the same as the coping level.

In addition to the four transit sheds, a warehouse for the storage of canned salmon or other merchandise will be constructed on the shore quay. This building will be about 200 ft. in length



New Pier at Vancouver Harb

View of Storage Yard for Pre-Cast Units.

by 82 ft. in width, three stories in height, all of reinforced concrete, and will be equipped with an electrical conveyor for the rapid handling of goods from vessels as well as spiral chutes and elevators for handling goods inside the warehouse.

Modern mechanical equipment for handling cargoes will be provided, consisting of a number of electrical cranes along the front of the sheds capable of handling cargo either to or from both floors of the sheds and the hold of the largest steamer afloat. Inside the sheds motor trucks, electrical conveyors, and elevators will be provided.

The approximate total cost of the Harbour Commissioners' work now being proceeded with, which, however, is only the first unit, is about £1,500,000, so that when this pier and transit sheds and warehouse are completed the Commissioners hope to have one of the most up-to-date, commodious, and best-equipped piers not only in Canada but in any other port in the world.

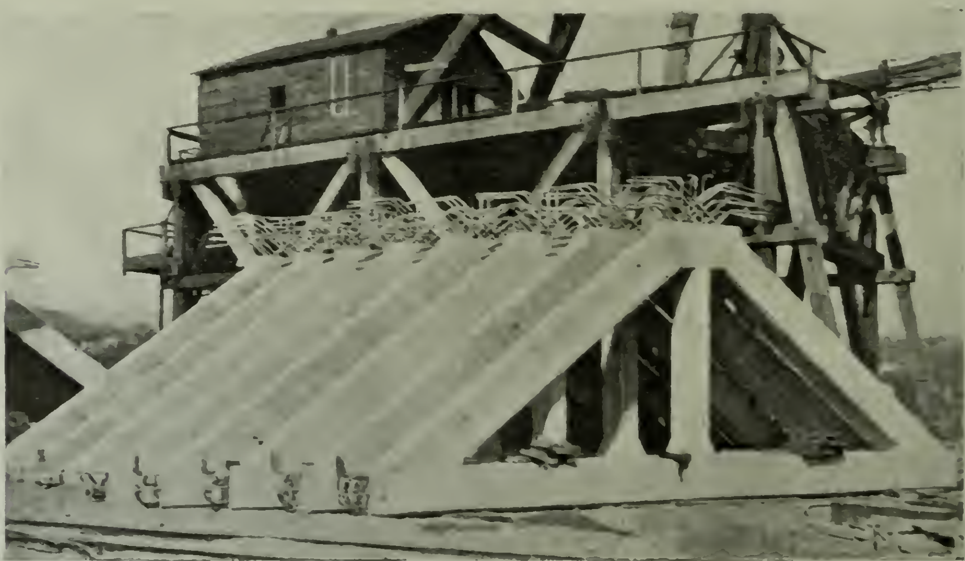
The unit lengths of the cylinder sections vary from 3 ft. to 18 ft., and the king post trusses, sheet piles, bearing piles, and beams are all of reinforced concrete. Many of the trusses weigh 25 tons. A

awing showing finished Structure.

Casting Yard for Pre-Cast Units.

special plant has been constructed for handling the long cylinders, the plant being capable of lifting 70 to 80 tons weight, and so far not a single cylinder is more than ¾ in. out of plumb, when finally sunk and sealed in place.

In addition to the new pier works for the Harbour Commissioners, a new floating dry dock is about to be constructed for the Burrard Dry Dock Co., Ltd. (Vancouver). This floating dry dock scheme is now substituted for the concrete dock which it was arranged about a year ago should be built for other interests. The floating dry dock scheme has been approved of by the Government at Ottawa, and will be constructed by private interests under the terms of the Dry Dock Subsidy Act. In connection therewith there will be a pier 700 ft. long by 50 ft. wide, all constructed of reinforced concrete. The general design will be somewhat of the same nature as has been adopted for the Ballantyne Pier, namely reinforced concrete cylinders filled inside with mass concrete. The floating dock will have a lifting capacity of 15,000 tons. Mr. A. D. Swan of Montreal is also the Engineer for the dry dock works.



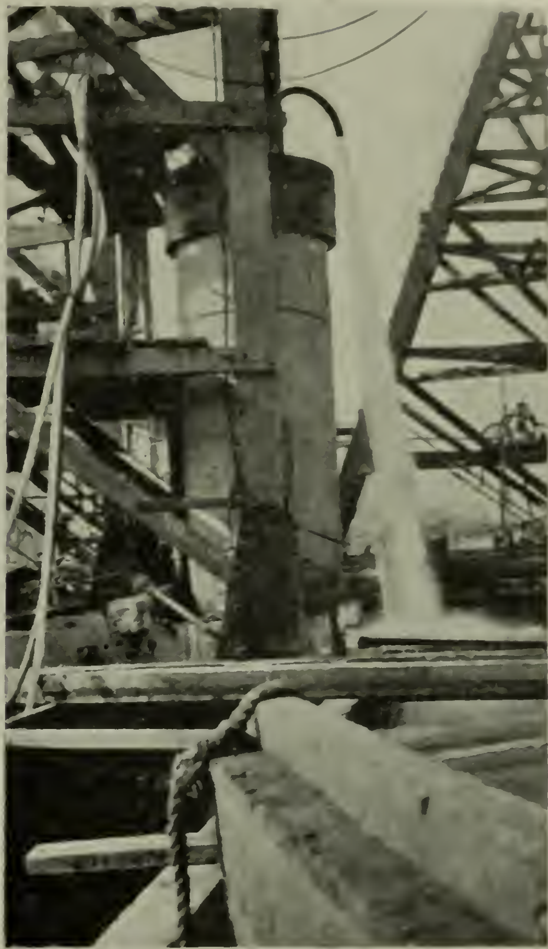
Pre-Cast Trusses.

CONCRETE OUTDOOR FURNITURE.

How much, we wonder, does the annual bill amount to for the repainting of the chairs and seats in our parks? Their number must run into hundreds of thousands, and in places such as St. James's Park and Hyde Park where they are very liberally disposed for the convenience of the public the charge under this heading must be a considerable item in the maintenance bill. The illustrations on pages 634 and 637 show how well adapted for the purpose is a material—concrete—which requires nothing but an occasional washing down to keep it in its original condition and which neither deteriorates owing to the action of rain nor blisters in the sun.

As is shown in these illustrations, concrete tables and seats are in no way incongruous when used for outdoor meals, and could be made to harmonise with the surroundings to a greater extent than iron and imitation marble tables and iron and wood chairs painted in a feeble attempt to match Nature's green in the surroundings.

The garden illustrated is situated in very pleasant surroundings in Avondale, a suburb of Cincinnati, and is known as "The Toadstool Garden."



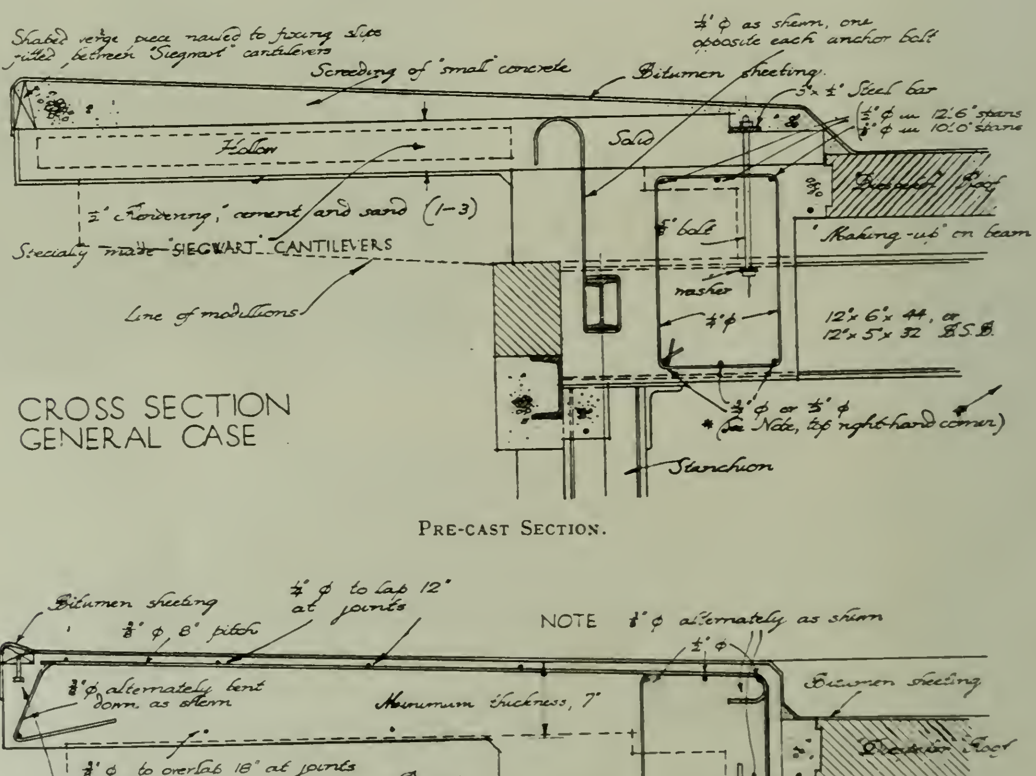
New Harbour Works at Vancouver: Cylinder in Process of Sinking. (*See* p. 660.)

New Harbour Works at Vancouver Cylinder Shoes. (*See* p. 660.)

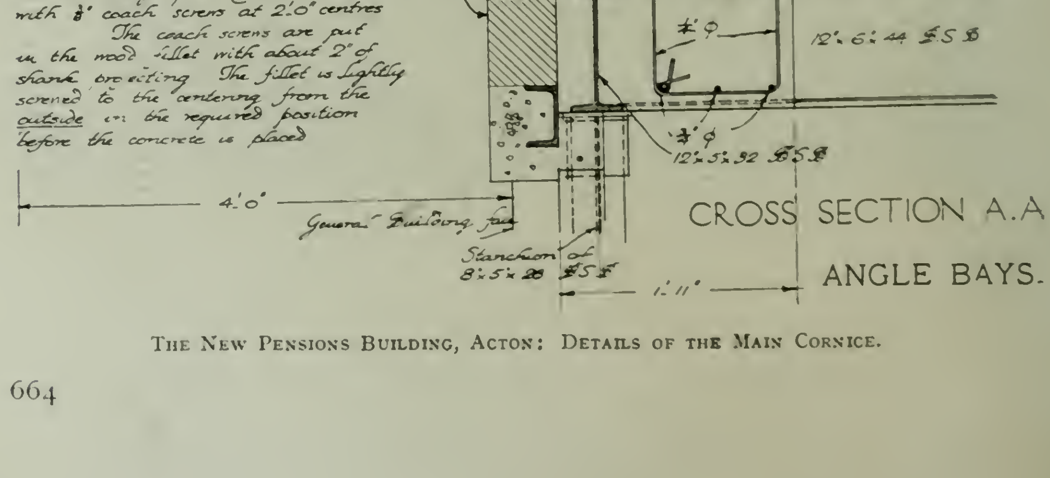
THE CORNICE AT THE NEW PENSIONS BUILDING.

We give on this page two detail drawings of the cornice on the new Pensions Building at Acton, which was fully illustrated in our August issue. This cornice, with its projection of 4 ft., has some unique features. The long straight runs at the sides of the building are composed of specially cast hollow reinforced concrete cantilevers anchored to a solid reinforced concrete beam which spans the main steel roof beams at their junctions with the front stanchions and forms the bed of the cornice. At the end bays and corners of the building it was decided to build the cornice homogeneous with the main beams. The cornice slabs are designed to carry their loads independently of the modillions, which are only reinforced to provide against accidental stresses. Expansion and contraction are provided for by "free" joints at certain places in walls, floors, roof, stringcourses, and cornice. The hollow slabs forming the long runs of the cornice were supplied by the Siegwart Fireproof Flooring Company.

The cornice was designed jointly by Mr. J. G. West, M.B.E., of H.M. Office of Works, the architect of the building, and the Structural Engineering Dept. of the Office of Works.



Pre-cast Section.



The New Pensions Building, Acton: Details of the Main Cornice.

STANDARDISATION IN THE PROPORTIONING OF CONCRETE.

On the next pages are some of the tables for the proportioning necessary to produce concretes of different compressive strengths, ranging from 1,500 lb. per sq. in. to 4,000 lb. per sq. in., referred to in our Editorial pages this month. These tables are the result of a very large and comprehensive series of tests undertaken at the Structural Materials Research Laboratory of the Lewis Institute, Chicago, by Mr. Duff Abrams (Professor in Charge of the Laboratory), and Mr. Stanton Walker (Associate Engineer), and are reprinted from Bulletin No. 9 of the Laboratory.

In an introduction to the tables the authors state: "The most striking features of the experiments on which these tables are based are that they bring out the fundamental relations between the quantity of mixing water and the quality of the resulting concrete, and show that the size and grading of the aggregate and the quantity of cement affect the strength of concrete only in so far as they influence the water requirements. These investigations have shown that the interrelation of strength and proportions of materials may be expressed by the following principles:

"1. The strength of a concrete mixture depends on the quantity of mixing water in the batch, expressed as a ratio to the volume of cement so long as the concrete is workable and the aggregates are clean and structurally sound. The strength of the concrete decreases as the water-ratio increases.

"2. The effect of differences in the quantity of cement is reflected by differences in the water-ratio. In richer mixtures, a given condition of workability can be produced with a lower water-ratio, and consequently give higher strengths.

"3. There is an intimate relation between the size and grading of the aggregate and the quantity of water required to produce concrete of a given workability. The strength of concrete is affected by the size and grading of aggregate only in so far as the quantity of mixing water is influenced by these variables, so long as the aggregate is not graded too coarse for proper workability. Finer aggregates require more water for a given plasticity and quantity of cement and therefore give lower strengths than the coarser aggregates.

"4. It is not necessary, or desirable, that the aggregate be proportioned according to any fixed grading; wide variations in gradings of aggregate may occur without affecting the quantity of mixing water or the quality of the concrete. The classification of all aggregate finer than ¼ in. as fine aggregate, and that above this size as coarse aggregate, is purely an arbitrary division. Aggregates separated into any sizes may be proportioned to give desired results, so long as the grading will give workable concrete. The separation of aggregates into two sizes is desirable to facilitate uniform proportioning of successive batches.

"5. Plasticity or workability is an essential requirement of concrete for structural purposes. If a high degree of workability is necessary, this factor must be taken into account in designing the mixture. It is essential that the workability be kept under proper control.

"Any combination of the constituent materials which produces concrete of a given water-ratio will result in concrete of approximately the same strength, so long as the concrete is workable. The foregoing statements embody the essential features of what has become known as the water-ratio theory of proportioning concrete. A casual examination of the tables will show the vital influence of the quantity of mixing water, by the differences in quantities of materials required for different conditions of workability, as indicated by the slump test. The effect of what may seem slight changes in the quantity of mixing water has been generally overlooked in earlier discussions of this subject."

The tables are intended to be applied for the following purposes to all types of concrete work in which plastic mixtures may be used:

1. To furnish a guide in the selection of mixtures to be used in preliminary investigations of the strength of concrete.

2. To indicate proportions which may be expected to produce concrete of a given strength under average conditions where control tests are not made.

3. To furnish a basis for comparing the relative economies of concretes made by combining aggregates of different sizes, when the workability and strength of the resulting concrete are taken into account. (In other words, it is not necessary to restrict aggregate sizes to those usually mentioned in specifications.)

4. To furnish a basis for making changes in proportion to compensate for variations in size and grading of aggregates or workability of the concrete during the progress of the work.

The tables are based on the following considerations:

1. The compressive strength of concrete at 28 days, tested in accordance with standardised methods, is taken as the basis of quality of concrete.

2. The essential features of the method of testing are:

a. Aggregates of known sieve analysis.

b. Aggregates in room-dry condition.

c. Unit volumes determined by standard methods.

d. Cement assumed to weigh 94 lb. per cu. ft.

e. Proportions by volume.

f. Hand-mixed concrete puddled in 6 by 12 in. cylinder forms.

g. Concrete cured in moist place until tested.

h. Tests made at age of 28 days.

i. Each value based on 5 or more specimens made on different days.

3. Studies of the average interrelation of strength of concrete, size and grading of aggregate, quantity of cement and quantity of mixing water for the range covered by these tables.

4. Selection of sieve analyses of aggregate to represent average of materials of size-classification shown.

5. Determination of the most economical proportions of fine and coarse aggregates for each of the other conditions.

6. Yield of concrete determined by measurements and weights of 6 by 12 in. cylinders.

Precautions in the Use of the Tables.

The following precautions to be observed in the use of tables are given:—

1. If the proportions to be used in the work are selected from the tables, without preliminary tests of the materials, and control tests are not made during the progress of the work, the mixtures in bold-faced type should be used.

2. Strengths were based on 28-day compression tests of 6 by 12-in. concrete cylinders puddled in the forms, cured in a damp place at normal temperatures and tested in a damp condition. Allowance must be made for lower strength resulting from temperatures below normal.

3. Portland cement should meet the requirements of the standard specifications.

4. Aggregate should be clean, structurally sound, and graded in size between the limits shown in the tables.

5. Concrete should be mixed at least 1 minute in a batch mixer of approved design.

6. In comparing the strengths of concrete specimens made on the work with the values in the tables, it is important that tests be made in accordance with standard methods.

7. The quantities of materials were based on measurements in the laboratory, using dry materials rodded or puddled into the measure. No allowance was made for waste.

8. The slump test should not be too strictly interpreted.

9. Proportions and quantities of materials may be interpolated for concrete strengths, aggregate sizes, and consistencies not covered by the tables.

[In the tables giving the quantities of materials required to produce concrete of a given strength, it should be noted that the standard American barrel contains 376 lb. or four bags of 94 lb. each.

Proportions for 1,500 lb. per sq. in. Concrete.

[Based on 28-day compressive strength of 6 by 12 in. cylinders. Proportions are expressed by volume as follows: Portland cement : fine aggregate : coarse aggregate—Thus 1 : 2·6 : 4·6 indicates 1 part by volume of Portland cement, 2·6 parts by volume of fine aggregate, and 4·6 parts by volume of coarse aggregate.]

Size of Coarse Aggregate	Slump, In	Proportions Using Fine Aggregate of Different Sizes: 0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ In
None	½ to 1	1:2.8	1:3.3	1:3.8	1:4.4	1:5.1
	3 " 4	1:2.4	1:2.8	1:3.3	1:3.8	1:4.5
	6 " 7	1:1.9	1:2.2	1:2.6	1:3.0	1:3.6
	8 " 10	1:1.4	1:1.6	1:1.8	1:2.1	1:2.5
No. 4 to ¾ in.	½ to 1	1:2.6:4.6	1:2.9:4.3	1:3.4:4.1	1:3.9:3.6	1:4.6:3.1
	3 " 4	1:2.3:4.0	1:2.6:3.8	1:2.9:3.6	1:3.4:3.3	1:4.1:2.8
	6 " 7	1:1.8:3.4	1:2.0:3.2	1:2.3:3.1	1:2.6:2.8	1:3.1:2.6
	8 " 10	1:1.1:2.5	1:1.3:2.4	1:1.5:2.4	1:1.7:2.3	1:2.1:2.0
No. 4 to 1 in.	½ to 1	1:2.4:5.3	1:2.7:5.2	1:3.1:5.0	1:3.5:4.7	1:4.3:4.3
	3 " 4	1:2.1:4.7	1:2.4:4.5	1:2.7:4.4	1:3.1:4.1	1:3.7:3.7
	6 " 7	1:1.6:3.9	1:1.8:3.8	1:2.1:3.7	1:2.4:3.5	1:2.9:3.3
	8 " 10	1:1.1:2.9	1:1.2:2.8	1:1.4:2.8	1:1.6:2.7	1:1.9:2.6
No. 4 to 1½ in.	½ to 1	1:2.4:6.0	1:2.7:5.9	1:3.1:5.8	1:3.5:5.4	1:4.1:5.1
	3 " 4	1:2.0:5.4	1:2.3:5.3	1:2.7:5.2	1:3.0:5.0	1:3.5:4.6
	6 " 7	1:1.6:4.4	1:1.8:4.3	1:2.0:4.3	1:2.3:4.1	1:2.7:3.9
	8 " 10	1:1.0:3.3	1:1.1:3.2	1:1.3:3.2	1:1.5:3.1	1:1.8:2.9
No. 4 to 2 in.	½ to 1	1:2.2:6.9	1:2.4:6.8	1:2.8:6.8	1:3.1:6.6	1:3.7:6.4
	3 " 4	1:1.8:6.2	1:2.0:6.1	1:2.4:6.1	1:2.7:6.0	1:3.1:5.7
	6 " 7	1:1.4:5.1	1:1.6:5.0	1:1.8:5.0	1:2.0:5.0	1:2.4:4.8
	8 " 10	1:0.9:3.8	1:1.0:3.8	1:1.1:3.8	1:1.3:3.8	1:1.5:3.7
⅜ to 1 in.	½ to 1	1:2.8:5.2	1:3.1:5.1	1:2.6:4.8	1:4.2:4.6	1:4.8:4.1
	3 " 4	1:2.4:4.5	1:2.6:4.5	1:3.1:4.3	1:3.6:4.0	1:4.1:3.6
	6 " 7	1:1.9:3.9	1:2.1:3.7	1:2.6:3.6	1:2.8:3.4	1:3.2:3.1
	8 " 10	1:1.3:2.8	1:1.4:2.8	1:1.6:2.7	1:1.9:2.6	1:2.2:2.4
⅜ to 1½ in.	½ to 1	1:2.8:5.8	1:3.1:5.7	1:3.5:5.6	1:4.1:5.3	1:4.7:4.9
	3 " 4	1:2.4:5.2	1:2.7:5.1	1:3.1:5.0	1:3.5:4.8	1:4.1:4.4
	6 " 7	1:1.9:4.3	1:2.1:4.2	1:2.4:4.2	1:2.7:4.0	1:3.1:3.7
	8 " 10	1:1.2:3.2	1:1.4:3.2	1:1.6:3.1	1:1.8:3.0	1:2.1:2.9
⅜ to 2 in.	½ to 1	1:2.7:6.6	1:3.0:6.6	1:3.4:6.5	1:3.9:6.4	1:4.4:6.0
	3 " 4	1:2.3:5.9	1:2.6:5.9	1:2.9:5.8	1:3.3:5.6	1:3.7:5.5
	6 " 7	1:1.8:4.9	1:2.0:4.8	1:2.2:4.8	1:2.6:4.8	1:3.0:4.5
	8 " 10	1:1.2:3.7	1:1.3:3.7	1:1.5:3.7	1:1.7:3.6	1:1.9:3.5
¾ to 1½ in.	½ to 1	1:3.2:5.4	1:3.6:5.3	1:4.1:5.1	1:4.7:4.8	1:5.3:4.4
	3 " 4	1:2.8:4.8	1:3.2:4.8	1:3.6:4.6	1:4.0:4.4	1:4.6:4.0
	6 " 7	1:2.1:4.0	1:2.5:4.0	1:2.8:3.9	1:3.2:3.7	1:3.5:3.4
	8 " 10	1:1.5:3.0	1:1.7:3.0	1:1.9:2.9	1:2.2:2.8	1:2.5:2.7
¾ to 2 in.	½ to 1	1:3.2:6.3	1:3.6:6.1	1:4.0:6.0	1:4.6:5.8	1:5.2:5.4
	3 " 4	1:2.8:5.5	1:3.1:5.5	1:3.5:5.4	1:3.9:5.3	1:4.5:4.9
	6 " 7	1:2.1:4.5	1:2.4:4.6	1:2.7:4.5	1:3.1:4.4	1:3.5:4.1
	8 " 10	1:1.4:3.4	1:1.6:3.4	1:1.8:3.4	1:2.1:3.4	1:2.4:3.3
¾ to 3 in.	½ to 1	1:3.3:7.1	1:3.6:7.1	1:4.0:7.0	1:4.6:6.9	1:5.3:6.6
	3 " 4	1:2.7:6.3	1:3.0:6.3	1:3.4:6.3	1:4.0:6.3	1:4.6:5.9
	6 " 7	1:2.1:5.1	1:2.4:5.2	1:2.7:5.2	1:3.1:5.1	1:3.5:4.9
	8 " 10	1:1.4:3.8	1:1.6:3.9	1:1.8:3.9	1:2.1:3.9	1:2.4:3.8

Quantities of Materials for 1 cu. yd. of 1,500 lb. per sq. in. Concrete.

[The volume of cement is expressed in barrels and of aggregates in cubic yards. F = fine aggregate; C = coarse aggregate. Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement 2 per cent.; fine aggregate, 10 per cent.; coarse aggregate, 5 per cent.]

Quantities of Materials Using Fine Aggregate of Different Sizes

Size of Coarse Aggregate	Slump, In.	0-No. 30 Cement	0-No. 30 Aggregate F.	0-No. 30 Aggregate C.	0-No. 16 Cement	0-No. 16 Aggregate F.	0-No. 16 Aggregate C.	0-No. 8 Cement	0-No. 8 Aggregate F.	0-No. 8 Aggregate C.	0-No. 4 Cement	0-No. 4 Aggregate F.	0-No. 4 Aggregate C.	0-⅜ In Cement	0-⅜ In Aggregate F.	0-⅜ In Aggregate C.
None	½ to 1	1.90	.79		1.77	.84		1.60	.90		1.36	.89		1.27	.98	
	3 " 4	2.12	.75		1.96	.81		1.76	.86		1.52	.86		1.38	.93	
	6 " 7	2.49	.70		2.33	.76		2.08	.80		1.81	.80		1.64	.88	
	8 " 10	2.98	.62		2.82	.67		2.36	.70		2.32	.72		2.10	.78	
No. 4 to ¾ in.	½ to 1	1.02	.39	.69	1.03	.44	.66	1.01	.51	.61	.98	.56	.52	.93	.67	.45
	3 " 4	1.17	.40	.69	1.12	.43	.63	1.11	.48	.59	1.07	.64	.51	1.08	.65	.46
	6 " 7	1.39	.37	.70	1.36	.40	.64	1.31	.45	.60	1.30	.50	.54	1.27	.58	.47
	8 " 10	1.76	.29	.66	1.76	.34	.63	1.73	.38	.61	1.68	.42	.56	1.67	.52	.49
No. 4 to 1 in.	½ to 1	.98	.36	.77	.98	.39	.76	.96	.44	.71	.94	.49	.65	.93	.59	.59
	3 " 4	1.08	.34	.75	1.06	.38	.70	1.05	.42	.68	1.02	.47	.62	1.02	.56	.56
	6 " 7	1.32	.31	.76	1.30	.35	.73	1.23	.38	.67	1.21	.43	.63	1.21	.52	.59
	8 " 10	1.70	.28	.73	1.68	.30	.70	1.64	.34	.68	1.60	.38	.64	1.67	.44	.58
No. 4 to 1½ in.	½ to 1	.93	.33	.83	.93	.37	.81	.91	.42	.78	.88	.46	.70	.88	.52	.65
	3 " 4	1.02	.30	.81	1.03	.35	.81	1.01	.40	.78	.98	.43	.72	.97	.50	.66
	6 " 7	1.24	.29	.81	1.23	.33	.78	1.18	.35	.75	1.12	.38	.68	1.15	.46	.66
	8 " 10	1.62	.24	.79	1.59	.26	.75	1.64	.30	.73	1.50	.33	.69	1.50	.40	.64
No. 4 to 2 in.	½ to 1	.88	.29	.90	.88	.31	.88	.85	.35	.86	.82	.38	.80	.80	.44	.76
	3 " 4	.98	.26	.90	.99	.29	.89	.96	.34	.87	.93	.37	.82	.91	.42	.77
	6 " 7	1.17	.27	.88	1.16	.28	.86	1.13	.30	.84	1.09	.32	.81	1.09	.39	.78
	8 " 10	1.63	.20	.86	1.49	.23	.84	1.46	.24	.82	1.43	.27	.80	1.43	.33	.78
⅜ to 1 in.	½ to 1	1.00	.41	.77	.97	.44	.73	.95	.51	.68	.91	.56	.62	.92	.65	.56
	3 " 4	1.08	.38	.75	1.06	.40	.70	1.03	.47	.65	1.00	.53	.59	1.02	.62	.54
	6 " 7	1.32	.37	.76	1.27	.40	.70	1.25	.44	.67	1.20	.50	.60	1.21	.57	.56
	8 " 10	1.73	.33	.72	1.69	.35	.70	1.66	.39	.66	1.59	.45	.61	1.54	.50	.55
⅜ to 1½ in.	½ to 1	.92	.38	.80	.91	.43	.77	.90	.47	.73	.86	.52	.67	.88	.59	.62
	3 " 4	1.03	.37	.79	1.01	.40	.76	1.00	.46	.74	.95	.49	.68	.96	.58	.62
	6 " 7	1.22	.34	.78	1.21	.38	.75	1.16	.42	.73	1.17	.47	.69	1.13	.52	.62
	8 " 10	1.67	.29	.77	1.60	.33	.76	1.54	.36	.71	1.48	.39	.66	1.46	.45	.63
⅜ to 2 in.	½ to 1	.88	.35	.86	.86	.38	.84	.83	.42	.80	.79	.45	.76	.77	.50	.63
	3 " 4	.96	.33	.85	.97	.37	.85	.95	.41	.81	.91	.44	.75	.90	.49	.73
	6 " 7	1.16	.31	.84	1.14	.34	.81	1.11	.36	.79	1.08	.42	.77	1.07	.48	.71
	8 " 10	1.51	.28	.87	1.60	.29	.82	1.48	.32	.79	1.40	.35	.75	1.38	.39	.71
¾ to 1½ in.	½ to 1	.91	.43	.73	.89	.47	.70	.87	.53	.66	.83	.57	.58	.81	.63	.53
	3 " 4	1.00	.41	.71	1.00	.47	.71	.97	.52	.66	.93	.55	.60	.91	.63	.54
	6 " 7	1.20	.37	.71	1.20	.44	.71	1.15	.48	.66	1.11	.53	.61	1.08	.56	.54
	8 " 10	1.60	.36	.71	1.57	.39	.70	1.53	.43	.65	1.44	.47	.60	1.43	.53	.57
¾ to 2 in.	½ to 1	.85	.40	.78	.85	.45	.77	.80	.47	.71	.76	.52	.66	.74	.57	.58
	3 " 4	.96	.40	.78	.95	.44	.77	.93	.48	.73	.84	.48	.65	.86	.57	.52
	6 " 7	1.14	.38	.76	1.14	.41	.78	1.08	.43	.73	1.03	.47	.67	1.04	.54	.63
	8 " 10	1.50	.31	.76	1.46	.35	.73	1.43	.38	.73	1.37	.43	.69	1.34	.48	.65
¾ to 3 in.	½ to 1	.78	.37	.82	.76	.46	.80	.72	.43	.75	.67	.46	.68	.65	.50	.61
	3 " 4	.91	.38	.85	.89	.40	.82	.86	.43	.80	.81	.48	.74	.79	.53	.69
	6 " 7	1.04	.33	.70	1.04	.37	.80	1.03	.41	.79	.98	.45	.88	.96	.51	.72
	8 " 10	1.43	.30	.80	1.39	.33	.80	1.35	.38	.76	1.30	.40	.75	1.25	.44	.70

Proportions for 2,000 lb. per sq. in. Concrete.

[Based on 28-day compressive strength of 6 by 12 in. cylinders. Proportions are expressed by volume as follows: Portland cement : fine aggregate : coarse aggregate—Thus 1 : 2·6 : 4·6 indicates 1 part by volume of Portland cement, 2·6 parts by volume of fine aggregate, and 4·6 parts by volume of coarse aggregate.]

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ in.
None	½ to 1	1:2.2	1:2.6	1:3.0	1:3.5	1:4.1
	3 " 4	1:1.9	1:2.2	1:2.6	1:3.0	1:3.5
	6 " 7	1:1.5	1:1.7	1:2.0	1:2.3	1:2.7
	8 " 10	1:1.0	1:1.1	1:1.3	1:1.6	1:1.8
No. 4 to ¾ in.	½ to 1	1:2.1:3.8	1:2.3:3.7	1:2.6:3.5	1:3.0:3.1	1:3.6:2.8
	3 " 4	1:1.7:3.3	1:1.9:3.2	1:2.2:3.1	1:2.6:2.8	1:3.0:2.4
	6 " 7	1:1.3:2.7	1:1.4:2.6	1:1.7:2.5	1:1.9:2.3	1:2.3:2.1
	8 " 10	1:0.8:1.9	1:0.9:1.9	1:1.0:1.8	1:1.2:1.7	1:1.5:1.6
No. 4 to 1 in.	½ to 1	1:1.9:4.5	1:2.2:4.3	1:2.5:4.2	1:2.8:3.9	1:3.4:3.6
	3 " 4	1:1.6:3.9	1:1.8:3.8	1:2.1:3.7	1:2.4:3.5	1:2.8:3.2
	6 " 7	1:1.2:3.1	1:1.3:3.1	1:1.5:3.0	1:1.8:2.9	1:2.1:2.7
	8 " 10	1:0.7:2.2	1:0.8:2.2	1:1.0:2.3	1:1.1:2.1	1:1.3:2.0
No. 4 to 1½ in.	½ to 1	1:1.9:5.0	1:2.1:4.9	1:2.4:4.9	1:2.7:4.6	1:3.2:4.4
	3 " 4	1:1.6:4.4	1:1.7:4.3	1:2.0:4.2	1:2.4:4.0	1:2.7:3.8
	6 " 7	1:1.1:3.5	1:1.3:3.5	1:1.4:3.5	1:1.7:3.4	1:2.0:3.2
	8 " 10	1:0.7:2.5	1:0.8:2.5	1:0.9:2.5	1:1.0:2.4	1:1.2:2.3
No. 4 to 2 in.	½ to 1	1:1.7:5.8	1:1.9:5.7	1:2.2:5.8	1:2.4:5.6	1:2.8:5.5
	3 " 4	1:1.4:5.0	1:1.5:5.0	1:1.8:5.0	1:2.0:4.9	1:2.3:4.7
	6 " 7	1:1.0:4.1	1:1.1:4.1	1:1.2:4.1	1:1.4:4.1	1:1.7:3.9
	8 " 10	1:0.6:2.9	1:0.7:2.9	1:0.7:3.0	1:0.8:2.9	1:1.0:2.9
⅜ to 1 in.	½ to 1	1:2.2:4.4	1:2.5:4.2	1:2.8:4.1	1:3.3:3.8	1:3.8:3.4
	3 " 4	1:1.9:3.8	1:2.1:3.7	1:2.4:3.6	1:2.8:3.4	1:3.2:3.1
	6 " 7	1:1.4:3.1	1:1.5:3.0	1:1.8:3.0	1:2.1:2.8	1:2.4:2.5
	8 " 10	1:0.9:2.2	1:1.0:2.2	1:1.1:2.2	1:1.3:2.0	1:1.5:1.9
⅜ to 1½ in.	½ to 1	1:2.2:4.9	1:2.5:4.8	1:2.8:4.7	1:3.2:4.6	1:3.7:4.2
	3 " 4	1:1.9:4.3	1:2.1:4.2	1:2.4:4.1	1:2.7:4.0	1:3.1:3.7
	6 " 7	1:1.4:3.5	1:1.5:3.4	1:1.7:3.4	1:2.0:3.3	1:2.3:3.1
	8 " 10	1:0.9:2.5	1:1.0:2.5	1:1.1:2.4	1:1.3:2.4	1:1.5:2.3
⅜ to 2 in.	½ to 1	1:2.1:5.6	1:2.3:5.5	1:2.6:5.5	1:3.0:5.4	1:3.5:5.1
	3 " 4	1:1.7:4.8	1:2.0:4.8	1:2.2:4.8	1:2.5:4.7	1:2.9:4.4
	6 " 7	1:1.3:4.0	1:1.4:3.9	1:1.6:3.9	1:1.8:3.9	1:2.1:3.8
	8 " 10	1:0.8:2.9	1:0.9:2.9	1:1.0:2.9	1:1.2:2.9	1:1.3:2.8
¾ to 1½ in.	½ to 1	1:2.6:4.5	1:2.9:4.5	1:3.3:4.4	1:3.8:4.2	1:4.3:3.9
	3 " 4	1:2.2:3.9	1:2.5:3.9	1:2.8:3.8	1:3.2:3.6	1:3.6:3.3
	6 " 7	1:1.6:3.2	1:1.8:3.2	1:2.1:3.1	1:2.4:3.0	1:2.7:2.8
	8 " 10	1:1.0:2.3	1:1.2:2.3	1:1.4:2.2	1:1.6:2.2	1:1.8:2.1
¾ to 2 in.	½ to 1	1:2.5:5.2	1:2.8:5.2	1:3.2:5.1	1:3.6:5.0	1:4.1:4.7
	2 " 4	1:2.1:4.5	1:2.4:4.5	1:2.7:4.4	1:3.1:4.3	1:3.5:4.0
	6 " 7	1:1.6:3.7	1:1.8:3.7	1:2.0:3.7	1:2.3:3.6	1:2.6:3.5
	8 " 10	1:1.0:2.6	1:1.1:2.7	1:1.3:2.6	1:1.5:2.7	1:1.7:2.6
¾ to 3 in.	½ to 1	1:2.5:6.0	1:2.9:5.9	1:3.2:5.9	1:3.6:5.8	1:4.1:5.6
	3 " 4	1:2.1:5.1	1:2.4:5.2	1:2.7:5.2	1:3.1:5.1	1:3.5:4.9
	6 " 7	1:1.5:4.1	1:1.7:4.2	1:2.0:4.2	1:2.3:4.2	1:2.5:4.0
	8 " 10	1:1.0:2.9	1:1.1:3.0	1:1.3:3.0	1:1.5:3.0	1:1.7:3.0

Quantities of Materials for 1 cu. yd. of 2,000 lb. per sq. in. Concrete.

[The volume of cement is expressed in barrels and of aggregates in cubic yards: F = fine aggregate; C = coarse aggregate. Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement, 2 per cent.; fine aggregate, 10 per cent.; coarse aggregate, 5 per cent.]

Size of Coarse Aggregate	Slump, in.	Quantities of Materials Using Fine Aggregate of Different Sizes														
		0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-⅜ in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	2.31	.75		2.12	.82		1.92	.85		1.65	.85		1.42	.86	
	3 " 4	2.55	.72		2.39	.78		2.12	.82		1.85	.82		1.71	.89	
	6 " 7	2.94	.65		2.53	.71		2.52	.75		2.24	.76		2.00	.83	
	8 " 10	3.60	.53		3.54	.58		3.25	.62		2.80	.66		2.62	.70	
No. 4 to ¾ in.	½ to 1	1.27	.40	.71	1.24	.42	.68	1.19	.46	.62	1.17	.52	.54	1.17	.62	.48
	3 " 4	1.43	.36	.70	1.40	.39	.66	1.36	.44	.62	1.34	.51	.56	1.32	.59	.47
	6 " 7	1.71	.33	.68	1.70	.35	.66	1.66	.42	.61	1.60	.45	.54	1.59	.54	.50
	8 " 10	2.25	.27	.63	2.23	.30	.63	2.20	.33	.59	2.13	.38	.54	2.10	.47	.50
No. 4 to 1 in.	½ to 1	1.19	.33	.79	1.17	.38	.74	1.13	.42	.70	1.16	.46	.64	1.09	.55	.58
	3 " 4	1.36	.32	.78	1.32	.35	.74	1.26	.39	.69	1.24	.44	.64	1.24	.51	.59
	6 " 7	1.65	.29	.76	1.62	.31	.74	1.56	.35	.69	1.52	.40	.65	1.51	.47	.60
	8 " 10	2.15	.22	.70	2.13	.25	.69	2.07	.31	.70	2.01	.33	.63	1.98	.38	.59
No. 4 to 1½ in.	½ to 1	1.10	.31	.81	1.09	.34	.79	1.07	.38	.78	1.05	.42	.71	1.04	.49	.68
	3 " 4	1.26	.30	.82	1.25	.31	.79	1.20	.35	.74	1.17	.42	.69	1.16	.46	.65
	6 " 7	1.54	.25	.80	1.52	.29	.79	1.47	.30	.76	1.44	.36	.72	1.43	.42	.68
	8 " 10	2.04	.21	.75	2.00	.24	.74	1.94	.26	.72	1.88	.28	.67	1.88	.33	.64
No. 4 to 2 in.	½ to 1	1.04	.26	.89	1.05	.29	.88	1.04	.32	.89	1.00	.35	.83	.98	.41	.80
	3 " 4	1.20	.25	.89	1.19	.26	.88	1.16	.31	.86	1.11	.33	.80	1.12	.38	.78
	6 " 7	1.47	.22	.80	1.45	.24	.88	1.38	.25	.84	1.35	.28	.82	1.36	.34	.79
	8 " 10	1.92	.17	.82	1.89	.20	.81	1.85	.19	.82	1.81	.21	.78	1.80	.27	.77
⅜ to 1 in.	½ to 1	1.17	.38	.76	1.16	.43	.72	1.12	.46	.68	1.10	.54	.62	1.10	.62	.55
	3 " 4	1.34	.38	.75	1.33	.41	.73	1.29	.46	.69	1.23	.51	.62	1.23	.58	.56
	6 " 7	1.67	.35	.77	1.63	.36	.72	1.57	.42	.70	1.51	.47	.63	1.53	.54	.57
	8 " 10	2.16	.29	.70	2.12	.31	.69	2.06	.34	.67	2.01	.39	.60	1.93	.43	.54
⅜ to 1½ in.	½ to 1	1.10	.36	.80	1.07	.40	.76	1.05	.43	.73	1.02	.48	.69	1.03	.56	.64
	3 " 4	1.25	.35	.79	1.24	.39	.77	1.21	.43	.73	1.16	.46	.69	1.15	.53	.63
	6 " 7	1.54	.32	.80	1.52	.34	.77	1.47	.37	.74	1.42	.42	.69	1.41	.48	.65
	8 " 10	2.05	.27	.76	2.00	.29	.74	1.93	.31	.70	1.89	.36	.67	1.83	.41	.62
⅜ to 2 in.	½ to 1	1.05	.33	.85	1.03	.35	.84	1.01	.39	.82	.98	.43	.78	.97	.50	.73
	3 " 4	1.19	.30	.85	1.18	.35	.84	1.14	.37	.81	1.10	.41	.76	1.09	.47	.71
	6 " 7	1.46	.28	.86	1.45	.30	.84	1.40	.33	.81	1.33	.35	.77	1.31	.41	.74
	8 " 10	1.91	.23	.82	1.88	.25	.81	1.83	.27	.79	1.80	.32	.77	1.74	.34	.72
¾ to 1½ in.	½ to 1	1.07	.41	.71	1.06	.45	.71	1.02	.50	.66	.98	.55	.61	.98	.62	.57
	3 " 4	1.23	.40	.71	1.23	.45	.71	1.19	.49	.67	1.12	.53	.60	1.10	.59	.54
	6 " 7	1.51	.36	.72	1.49	.40	.71	1.45	.45	.67	1.36	.48	.60	1.36	.54	.58
	8 " 10	2.01	.30	.69	1.97	.36	.67	1.91	.40	.62	1.81	.43	.59	1.79	.48	.56
¾ to 2 in.	½ to 1	1.02	.38	.79	1.02	.42	.78	.99	.47	.76	.94	.50	.70	.93	.56	.65
	3 " 4	1.17	.36	.78	1.16	.41	.77	1.11	.44	.72	1.05	.48	.67	1.04	.54	.61
	6 " 7	1.44	.34	.79	1.41	.38	.77	1.37	.41	.75	1.31	.45	.70	1.26	.48	.65
	8 " 10	1.88	.28	.72	1.85	.20	.74	1.82	.35	.70	1.74	.39	.69	1.70	.43	.65
¾ to 3 in.	½ to 1	.96	.36	.85	.95	.41	.83	.92	.44	.80	.88	.47	.75	.86	.52	.71
	3 " 4	1.08	.34	.81	1.08	.38	.83	1.05	.42	.81	1.00	.46	.76	.98	.51	.71
	6 " 7	1.36	.30	.83	1.30	.33	.81	1.28	.38	.80	1.23	.42	.77	1.20	.44	.71
	8 " 10	1.81	.27	.78	1.76	.29	.78	1.72	.33	.76	1.65	.37	.73	1.60	.40	.71

PROPORTIONS FOR 2,500 LB. PER SQ. IN. CONCRETE.

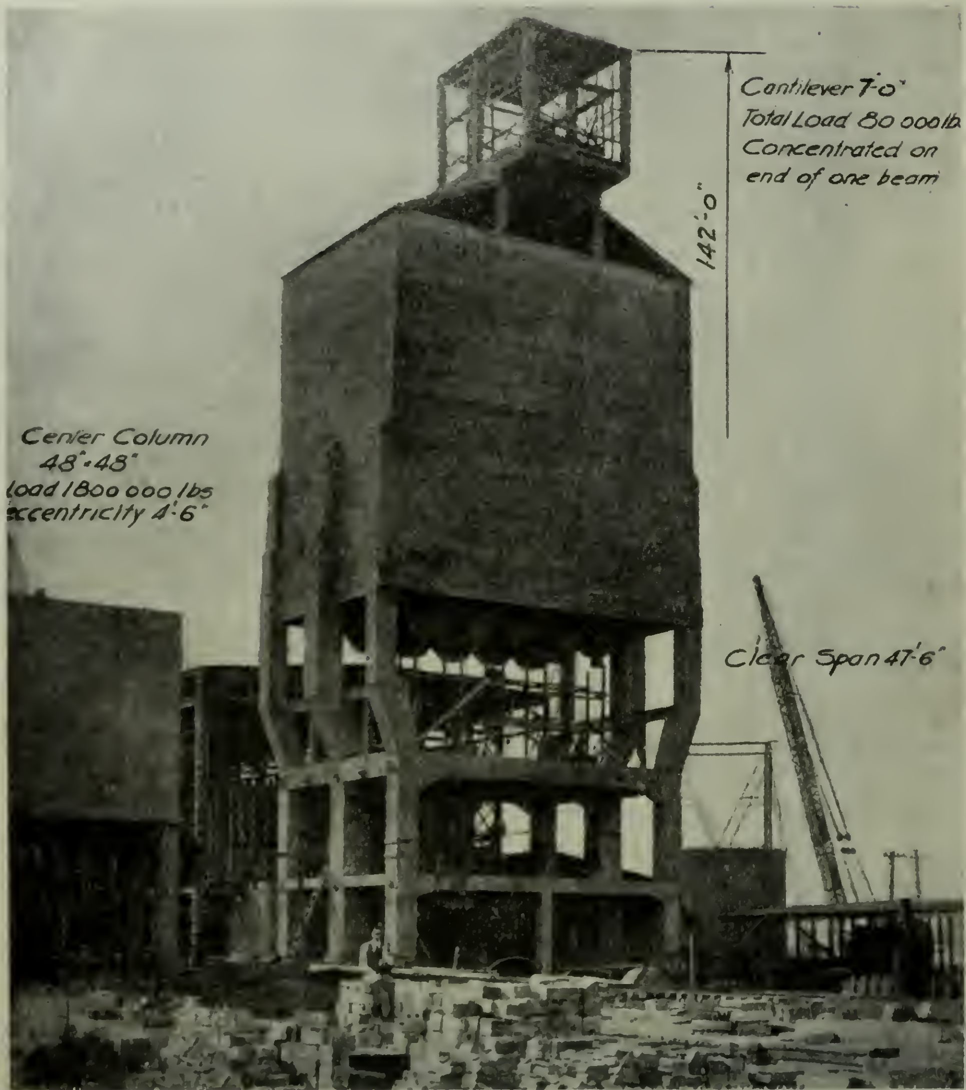
[Based on 28-day compressive strength of 6 by 12 in. cylinders. Proportions are expressed by volume as follows: Portland cement : fine aggregate : coarse aggregate—Thus 1 : 2·6 : 4·6 indicates 1 part of Portland cement, 2·6 parts by volume of fine aggregate and 4·6 parts by volume of coarse aggregate.]

Size of Coarse Aggregate	Slump, in	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ in.
None	½ to 1	1:1.8	1:2.1	1:2.4	1:2.9	1:3.3
	3 " 4	1:1.5	1:1.8	1:2.1	1:2.4	1:2.8
	6 " 7	1:1.1	1:1.3	1:1.6	1:1.8	1:2.1
	8 " 10	1:0.7	1:0.8	1:0.9	1:1.1	1:1.3
No. 4 to ¾ in.	½ to 1	1:1.6:3.2	1:1.8:3.1	1:2.1:3.0	1:2.4:2.7	1:2.9:2.4
	3 " 4	1:1.3:2.8	1:1.5:2.7	1:1.7:2.6	1:2.0:2.4	1:2.4:2.2
	6 " 7	1:1.0:2.2	1:1.1:2.2	1:1.3:2.1	1:1.5:2.0	1:1.8:1.8
	8 " 10	1:0.5:1.4	1:0.6:1.4	1:0.7:1.4	1:0.8:1.4	1:1.0:1.8
No. 4 to 1 in.	½ to 1	1:1.5:3.7	1:1.7:3.7	1:2.0:3.5	1:2.2:3.4	1:2.7:3.1
	3 " 4	1:1.2:3.3	1:1.4:3.2	1:1.6:3.1	1:1.9:3.0	1:2.2:2.7
	6 " 7	1:0.9:2.6	1:1.0:2.5	1:1.1:2.5	1:1.3:2.4	1:1.6:2.3
	8 " 10	1:0.5:1.7	1:0.6:1.7	1:0.6:1.7	1:0.7:1.6	1:0.9:1.6
No. 4 to 1½ in.	½ to 1	1:1.4:4.2	1:1.6:4.1	1:1.9:4.1	1:2.2:4.0	1:2.5:3.8
	3 " 4	1:1.2:3.7	1:1.3:3.6	1:1.5:3.6	1:1.8:3.5	1:2.1:3.3
	6 " 7	1:0.9:2.9	1:0.9:2.8	1:1.1:2.8	1:1.3:2.8	1:1.5:2.6
	8 " 10	1:0.5:1.9	1:0.5:1.9	1:0.6:1.9	1:0.7:1.8	1:0.8:1.8
No. 4 to 2 in.	½ to 1	1:1.3:4.9	1:1.4:4.8	1:1.6:4.9	1:1.9:4.8	1:2.2:4.7
	3 " 4	1:1.1:4.3	1:1.2:4.2	1:1.3:4.3	1:1.6:4.2	1:1.8:4.1
	6 " 7	1:0.7:3.3	1:0.8:3.3	1:0.9:3.4	1:1.1:3.3	1:1.2:3.3
	8 " 10	1:0.4:2.2	1:0.4:2.2	1:0.5:2.2	1:0.6:2.2	1:0.6:2.2
⅜ to 1 in.	½ to 1	1:1.8:3.7	1:2.0:3.6	1:2.3:3.5	1:2.6:3.3	1:3.0:2.9
	3 " 4	1:1.4:3.2	1:1.6:3.1	1:1.9:2.9	1:2.2:2.9	1:2.5:2.6
	6 " 7	1:1.0:2.5	1:1.2:2.5	1:1.3:2.4	1:1.6:2.3	1:1[illegible]:2.2
	8 " 10	1:0.6:1.6	1:0.7:1.6	1:0.8:1.6	1:0.9:1.6	1:1.0:1.5
⅜ to 1½ in.	½ to 1	1:1.7:4.1	1:1.9:4.1	1:2.2:4.0	1:2.5:3.9	1:2.9:3.6
	3 " 4	1:1.5:3.6	1:1.6:3.6	1:1.8:3.5	1:2.1:3.4	1:2.3:3.2
	6 " 7	1:1.0:2.9	1:1.2:2.8	1:1.3:2.8	1:1.5:2.7	1:1.8:2.6
	8 " 10	1:0.6:1.9	1:0.6:1.9	1:0.8:1.8	1:0.9:1.8	1:1.0:1.8
⅜ to 2 in.	½ to 1	1:1.7:4.7	1:1.8:4.7	1:2.1:4.7	1:2.4:4.6	1:2.7:4.4
	3 " 4	1:1.4:4.1	1:1.5:4.1	1:1.7:4.1	1:2.0:4.0	1:2.3:3.9
	6 " 7	1:1.0:3.2	1:1.1:3.2	1:1.2:3.2	1:1.4:3.2	1:1.6:3.1
	8 " 10	1:0.5:2.1	1:0.6:2.1	1:0.7:2.2	1:0.8:2.2	1:0.9:2.1
¾ to 1½ in.	½ to 1	1:2.0:3.8	1:2.3:3.8	1:2.6:3.7	1:3.0:3.6	1:3.4:3.3
	3 " 4	1:1.7:3.3	1:2.0:3.3	1:2.2:3.2	1:2.5:3.2	1:2.9:2.9
	6 " 7	1:1.2:2.6	1:1.4:2.6	1:1.6:2.6	1:1.9:2.5	1:2.1:2.3
	8 " 10	1:0.7:1.7	1:0.8:1.7	1:0.9:1.7	1:1.1:1.7	1:1.2:1.6
¾ to 2 in.	½ to 1	1:2.0:4.4	1:2.2:4.4	1:2.5:4.3	1:2.9:4.3	1:3.3:4.1
	3 " 4	1:1.7:3.8	1:1.9:3.8	1:2.1:3.8	1:2.5:3.7	1:2.8:3.6
	6 " 7	1:1.2:3.0	1:1.4:3.0	1:1.5:3.0	1:1.8:3.0	1:2.0:2.8
	8 " 10	1:0.7:2.0	1:0.8:2.0	1:0.9:2.0	1:1.0:2.0	1:1.2:2.0
¾ to 3 in.	½ to 1	1:2.0:5.0	1:2.2:5.0	1:2.5:5.0	1:2.7:5.0	1:3.2:4.7
	3 " 4	1:1.7:4.3	1:1.9:4.3	1:2.1:4.3	1:2.4:4.3	1:2.7:4.1
	6 " 7	1:1.2:3.3	1:1.4:3.4	1:1.5:3.4	1:1.8:3.4	1:2.0:3.3
	8 " 10	1:0.7:2.2	1:0.8:2.2	1:0.9:2.2	1:1.0:2.3	1:1.2:2.3

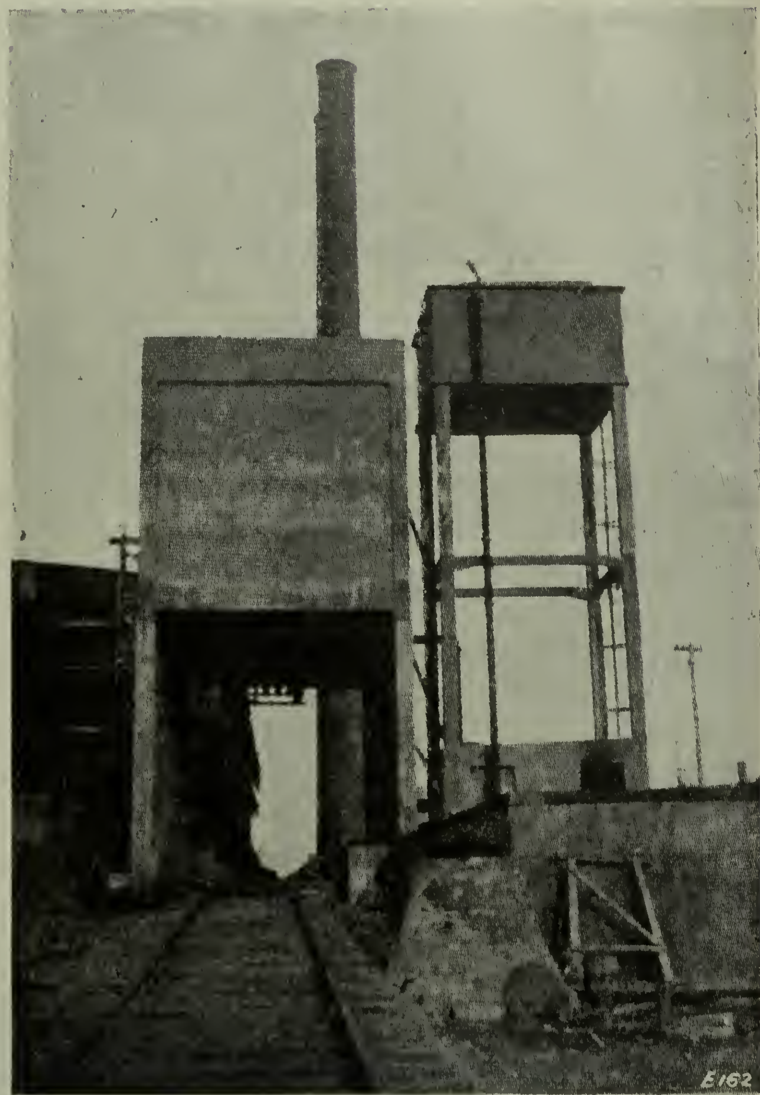
QUANTITIES OF MATERIALS FOR 1 CU. YD. OF 2,500 LB. PER SQ. IN. CONCRETE.

[The volume of cement is expressed in barrels and of aggregates in cubic yards: F = fine aggregate; C = coarse aggregate. Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement, 2 per cent.; fine aggregate, 10 per cent.; coarse aggregate, 5 per cent.]

Size of Coarse Aggregate	Slump, in.	Quantities of Materials Using Fine Aggregate of Different Sizes														
		0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-⅜ in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	2.71	.72		2.53	.79		2.30	.82		1.94	.83		1.83	.89	
	3 " 4	3.01	.67		2.78	.74		2.50	.78		2.20	.78		2.05	.85	
	6 " 7	3.60	.59		3.38	.65		2.97	.70		2.71	.72		2.45	.78	
	8 " 10	4.24	.44		4.11	.49		3.91	.52		3.46	.56		3.16	.61	
No. 4 to ¾ in.	½ to 1	1.49	.35	.70	1.46	.39	.67	1.42	.44	.63	1.39	.49	.55	1.39	.60	.49
	3 " 4	1.68	.32	.70	1.67	.37	.67	1.63	.41	.63	1.67	.46	.56	1.54	.55	.50
	6 " 7	2.06	.30	.67	2.03	.33	.66	1.98	.38	.62	1.89	.42	.56	1.89	.50	.50
	8 " 10	2.83	.21	.59	2.78	.25	.58	2.71	.28	.56	2.64	.31	.55	2.58	.38	.50
No. 4 to 1 in.	½ to 1	1.42	.32	.78	1.39	.35	.76	1.35	.40	.70	1.30	.42	.65	1.29	.51	.59
	3 " 4	1.61	.29	.79	1.56	.32	.74	1.51	.36	.69	1.48	.41	.65	1.47	.43	.59
	6 " 7	1.05	.26	.75	1.90	.28	.70	1.87	.30	.69	1.82	.35	.65	1.81	.43	.62
	8 " 10	2.68	.19	.65	2.64	.23	.66	2.54	.23	.64	2.50	.26	.59	2.56	.33	.55
No. 4 to 1½ in.	½ to 1	1.34	.27	.83	1.32	.31	.80	1.25	.35	.76	1.23	.40	.73	1.23	.45	.69
	3 " 4	1.50	.27	.82	1.48	.28	.79	1.43	.32	.76	1.39	.37	.72	1.39	.43	.65
	6 " 7	1.83	.24	.79	1.83	.24	.76	1.78	.29	.74	1.73	.33	.72	1.72	.38	.66
	8 " 10	2.50	.19	.70	2.49	.18	.70	2.42	.21	.68	2.40	.25	.64	2.39	.28	.64
No. 4 to 2 in.	½ to 1	1.25	.24	.91	1.24	.26	.88	1.21	.29	.88	1.17	.33	.83	1.13	.37	.79
	3 " 4	1.44	.23	.92	1.41	.25	.88	1.36	.26	.87	1.31	.31	.81	1.32	.35	.80
	6 " 7	1.77	.18	.87	1.75	.21	.86	1.70	.23	.86	1.65	.27	.81	1.63	.29	.80
	8 " 10	2.43	.14	.79	2.42	.14	.79	2.38	.18	.78	2.32	.21	.75	2.31	.20	.75
⅜ to 1 in.	½ to 1	1.41	.38	.77	1.39	.41	.74	1.34	.46	.69	1.29	.50	.63	1.29	.57	.55
	3 " 4	1.61	.33	.76	1.57	.37	.72	1.51	.42	.65	1.47	.48	.63	1.45	.54	.56
	6 " 7	1.97	.29	.73	1.91	.34	.71	1.87	.36	.66	1.83	.43	.62	1.78	.47	.58
	8 " 10	2.64	.23	.62	2.62	.27	.62	2.56	.30	.61	2.47	.33	.58	2.42	.36	.54
⅜ to 1½ in.	½ to 1	1.32	.33	.80	1.30	.37	.79	1.27	.41	.75	1.22	.45	.70	1.21	.52	.64
	3 " 4	1.49	.33	.79	1.48	.35	.79	1.43	.38	.74	1.38	.43	.69	1.37	.47	.65
	6 " 7	1.86	.28	.80	1.83	.33	.76	1.77	.34	.74	1.73	.38	.69	1.68	.45	.65
	8 " 10	2.49	.22	.70	2.46	.22	.69	2.41	.29	.64	2.38	.32	.63	2.32	.34	.62
⅜ to 2 in.	½ to 1	1.24	.31	.86	1.23	.33	.85	1.09	.34	.76	1.15	.41	.73	1.12	.46	.73
	3 " 4	1.41	.29	.85	1.40	.31	.85	1.35	.34	.82	1.29	.38	.76	1.28	.44	.74
	6 " 7	1.77	.26	.84	1.74	.28	.82	1.68	.30	.80	1.62	.34	.77	1.58	.38	.73
	8 " 10	2.41	.18	.76	2.37	.21	.74	2.32	.24	.76	2.30	.27	.75	2.22	.30	.69
¾ to 1½ in.	½ to 1	1.30	.38	.73	1.29	.44	.72	1.21	.47	.66	1.18	.52	.63	1.16	.58	.57
	3 " 4	1.47	.37	.72	1.45	.43	.71	1.40	.46	.66	1.35	.50	.64	1.32	.57	.57
	6 " 7	1.80	.32	.69	1.80	.37	.69	1.75	.42	.67	1.67	.47	.62	1.64	.51	.56
	8 " 10	2.48	.26	.63	2.45	.29	.62	2.40	.32	.60	2.31	.38	.58	2.27	.40	.54
¾ to 2 in.	½ to 1	1.22	.36	.79	1.23	.40	.79	1.18	.44	.75	1.10	.47	.70	1.07	.53	.65
	3 " 4	1.41	.35	.79	1.38	.39	.77	1.33	.41	.75	1.27	.47	.69	1.23	.51	.66
	6 " 7	1.74	.31	.77	1.70	.35	.76	1.66	.37	.74	1.58	.42	.70	1.53	.45	.64
	8 " 10	2.40	.25	.71	2.36	.28	.70	2.29	.31	.68	2.22	.33	.60	2.17	.38	.64
¾ to 3 in.	½ to 1	1.15	.34	.85	1.13	.37	.84	1.10	.41	.81	1.05	.42	.78	1.02	.48	.71
	3 " 4	1.32	.33	.84	1.30	.37	.83	1.25	.39	.79	1.21	.43	.77	1.18	.47	.72
	6 " 7	1.67	.30	.82	1.59	.33	.80	1.55	.34	.78	1.49	.40	.75	1.43	.43	.71
	8 " 10	2.32	.24	.75	2.37	.27	.74	2.20	.29	.72	2.13	.32	.73	2.12	.38	.72



COAL BIN FOR ST. LOUIS COKE AND CHEMICAL CO., GRANITE CITY, ILL. (*See p. 671.*)



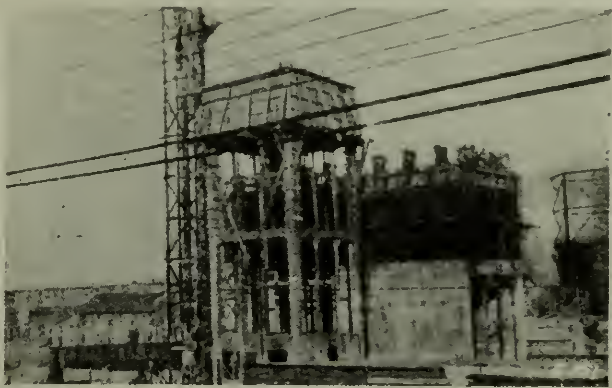
[*L. J. Mensch, Engineer.*

COKE QUENCHING PLANT.

Pig Iron Loading Plant.

SOME STRUCTURES OF UNUSUAL DESIGN FOR A CHEMICAL AND COKE COMPANY.

The accompanying illustrations and particulars from the *American Architect* may be of interest to our readers, inasmuch as they contain a number of unusual



Coal Mixing and Pulverising Plant, showing Steel Loading Trestle.

features in their design. They were erected for the Coke and Chemical Company at Granite City, Illinois, and designed by and carried out under the superintendence of Mr. L. J. Mensch, M. Amer. Soc. C.E. of Chicago.

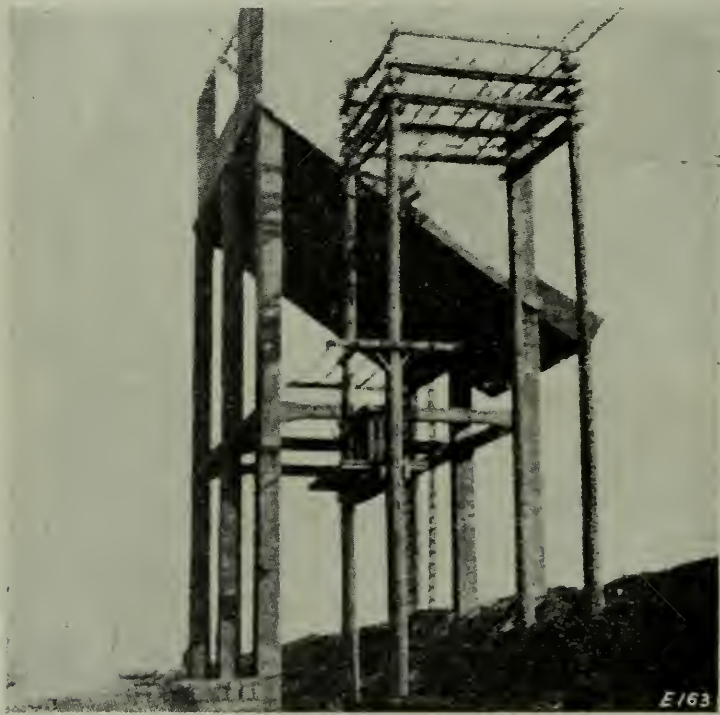
Coke Quenching Plant during Construction.

The coal bin serves to load the lorry cars used in charging the coke ovens. These cars are attached to a travelling crane and are loaded below openings in the bottom of the bin. The spacing of the lorry cars and the charging openings in the ovens are such that the width of the bin is fixed and requires a clearance of 47 ft. 6 in. beneath it. The pushers used for removing the hot coke from the ovens must pass the bin at a lower elevation and require an overall width of

46 ft. 6 in. between the outside faces of the columns. For this reason the larger columns at the centre of each side of the bin are offset 4 ft. 6 in.

The capacity of the bin is 1,900 tons of pulverised coal, which affords storage capacity for nearly four hours' use, as the lorry cars have a removal capacity of 50 tons per hour. The bin is charged through the monitor.

The bin portion of the structure is 32 ft. 8 in. by 50 ft. in size and 48 ft. high. The bin is divided into six cells by partitions. Those partitions connecting opposite columns are designed as beams with flange at top and bottom as shown in Section J J, and thus serve to transmit the load to the columns. Two longi-



Coke Loading Plant.

tudinal partitions are provided at the third points in the span and serve to act as stiffeners to the transverse walls to prevent buckling and to tie in the outer walls. These partitions have a large opening at the bottom and four small openings above, which facilitate the flow of the pulverised coal to the outlets in the floor. This diversion of the bin serves to bring the moments of the horizontal pressures of the walls down to reasonable amounts so that light walls will have sufficient strength. As the greater part of the load is applied to the cross-walls near this, bottom vertical bars are provided to distribute the stress over the entire cross section of the wall. These vertical rods diminish in size toward the top and are furnished in convenient lengths for handling. All rods are hooked on the ends and ample laps are provided at the splices.

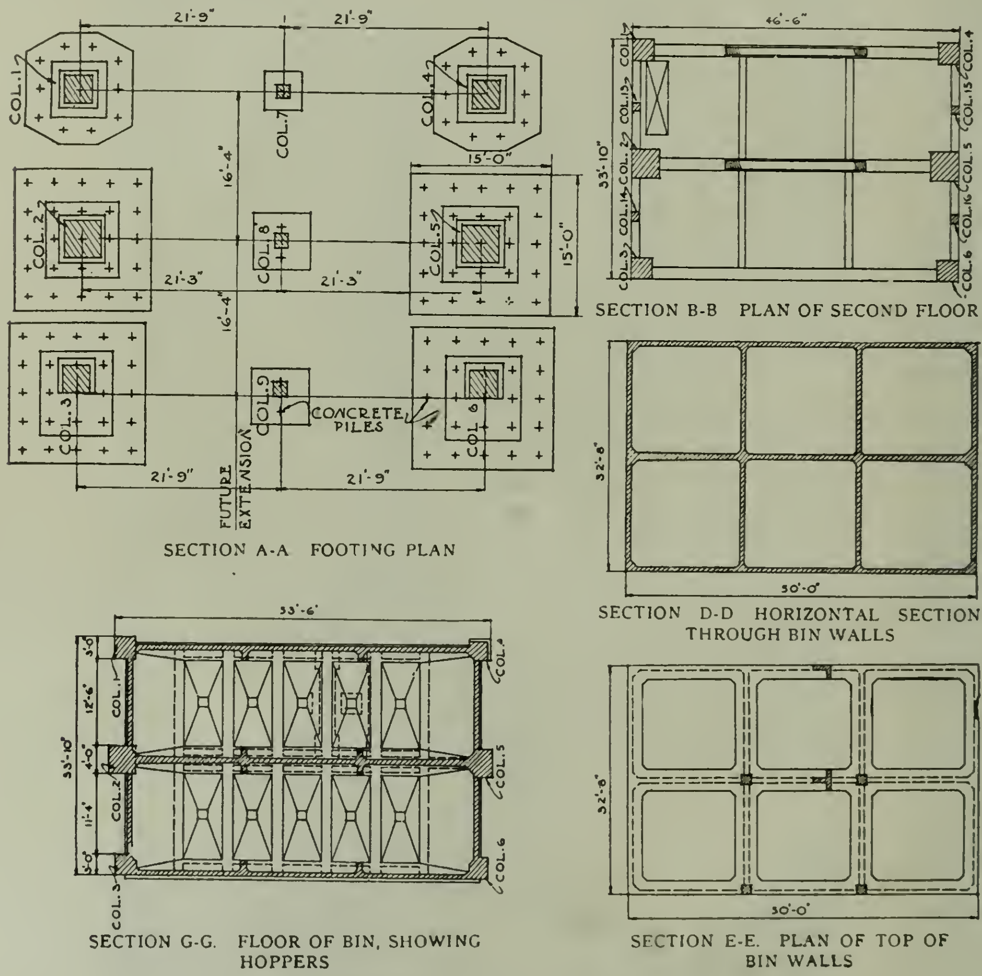
The columns 2 and 5 support the maximum load of 1,800,000 lb. and have an eccentricity of 4 ft. 6 in. They are 48 in. square and made of 1 : 1 : 2 concrete. The principal reinforcing consists of twenty $\frac{1}{4}$ in. square rods and a $\frac{5}{8}$ in. round spiral having a $1\frac{1}{2}$ in. pitch. On the tension side at the critical points there is placed additional reinforcement consisting of ten $1\frac{1}{4}$ in. square rods. At the point of bend the compression side has two small additional spirals made of $\frac{5}{16}$ in. round wire with $1\frac{1}{2}$ in. pitch and placed in the corners outside the main spiral. The six columns on the side of the bin extend up above the bottom of the bin about 20 ft. with the appearance of buttresses and thus take the load transmitted through the deep cross-wall beams. The foundations for columns 3 and 6 are made to support two more columns of similar size and loading which will form a

Blast Furnace Chimney.

part of an additional bin of the same size. The foundations rest on pre-cast reinforced concrete piles.

The chimneys are built of reinforced concrete and are 250 ft. high. The outer wall is 12 in. thick at the bottom and 5 in. thick at the top. The walls taper towards the top and the upper 30 ft. has no taper. They are well proportioned and graceful in appearance. The chimneys are lined with a 4 in. wall of firebrick throughout the entire height. At 50 ft. intervals a concrete shelf is built on the inside of the stack on which rests the lining. The blast furnace chimney has a minimum inside diameter of 7 ft. ; the two coke ovens chimneys have a minimum inside diameter of 9 ft. and the power house chimney one of 13 ft. 6 in.

The boiler feed water is purified in two circular reinforced concrete tanks in which is installed a mechanical agitator. A reinforced concrete trestle was



Coal Bin at Granite City, Ill.

built on which the pig iron is transported to a loading platform ; a reinforced coke loading plant was constructed which is supplied by apparatus supported by structural steel frame and not shown in the illustration. A reinforced coal storage mixing, crushing and pulverising building was constructed and is supplied with coal by means of a structural trestle. A coke quenching plant was built of reinforced concrete. This consists of a gravity water tank, cooling water basins or reservoirs, and an elevated structure made up of four walls which confine the spray and steam which arise from the flooding of the cars filled with hot coke.

THE ACTION OF SEA WATER ON CONCRETE.

At the recent annual convention of the American Society of Civil Engineers Mr. L. C. Wason (President of the Aberthaw Construction Co.) read a paper on the experiments which the Aberthaw Company is carrying out in Boston Harbour to test the action of sea water on concrete. The tests have been carried on for a good number of years, and it is interesting to note the author's conclusions that with good concrete and proper supervision the durability of concrete in sea water is assured unless a considerable amount of abrasion is present, in which case it will be wise to provide a protective covering.

A series of twenty-four test specimens, all 16 in. square in cross section by 16 ft. long, was made of various qualities of cement. Three different proportions of cement sand and broken stone and three different amounts of water were used. These were made in the first half of January, 1909, and were immersed in the sea at the Charlestown Navy Yard the last week of February, 1909. They were suspended so that, as the average height of the tide is 8 ft. 9 in., there was something over 3 ft. of specimen which would seldom be wet, and presumably never immersed, while about 3 ft. 6 in. projected below mean low mater, or grade zero, and therefore would never be uncovered.

After over thirteen years of immersion and study the lecturer thought it possible to make some tentative deductions as to the causes of failure, and how to design future structures so as to be as nearly proof against disintegration by sea water as possible, and we take the following extracts from his paper :—

The conditions in Boston Harbour are probably as severe as in any harbour of the United States, and there is considerable tide where the specimens hang ; they are attacked by waves, stirred up by the wind or the wash of ships, there is chance for a certain amount of abrasion from floating objects, there is freezing from severe northern winters, and there is attack from impurities (chemical or otherwise) present in sea water. In April, 1914, the U.S. Navy put fuel-oil pipes on the adjoining pier, and enough oil is spilled on the sea to have heavily coated the specimens from near their tops to low tide. In the opinion of the author this retards action by the sea, and therefore will extend for a longer period the full result of the sea water test, but has not entirely destroyed the value of the test.

On May 22, 1922, an examination of the specimens was made, and no appreciable change could be observed from the report of 1920. Of the twenty-four original specimens, two have been lost ; of the remaining twenty-two, five are in poor condition and may be considered to have failed so far as resistance to immersion in sea water goes. These were Nos. 7, 11, 13, 22, and 23, all mixed with 1 part cement, 3 sand, and 6 stone ; No. 7 was mixed dry, and the remainder wet. Four others show some deterioration, 2 of rich proportions mixed dry, and 2 of plastic and wet mixtures but of lean proportion. The remainder of the samples are in fairly good condition.

On May 24, 1922, specimens Nos. 7, 11, 22, and 23 were removed for testing purposes. Number 7 was made of three average Portland cements in equal parts, thoroughly mixed together. Number 11 was made of white Portland cement, very wet. Number 22 was made of nine-tenths of the same cement as No. 7, and one-tenth of hydrated lime, very wet. Number 23 was made of cement like No. 7, plus Sylvester solution of soap and alum, very wet.

When the specimens came out of the water there was about $\frac{1}{4}$ in. of sticky adhesion of fuel oil and dirt at the tops, which towards the low-water-mark became thinner, with a harder surface, somewhat glossy. Below low water there were no signs of oil, but the specimens were coated with live mussels, which showed that the water impurities were chiefly those floating on the surface and not sufficient to kill marine life. The oil did not penetrate very deep into existing cracks, and where a fresh fracture of concrete occurred there was no evidence of any penetration of oil below the surface of even the poorest specimens. Discoloration was not more than one thirty-second of an inch deep. In all these specimens the portions most damaged, namely, near mid-tide, showed rather disintegrated and soft concrete.

The specimens were cut into sections

and tested in a crushing machine at the Massachussetts Institute of Technology on June 7 last. The testing was carried to the point of failure of the specimen. Cracks appeared longitudinally, and formed roughly two prisms of hour-glass shape. Wherever reinforcing steel was exposed after the tests it appeared bright. The most porous specimen of all, No. 7, was so broken afterwards that the reinforcing bar was entirely removed. With the exception of three spots about one-quarter inch in diameter which showed rust the bar was entirely bright. This was from the lower end, which had been permanently immersed for over thirteen years.

The result of the crushing test is given in the following table.

month before being subjected to the tidal action of the sea. Two rows nearest the shore, being out of water except during high tide and never having emersion of more than about 3 ft., were cast between tides. An examination of these was made on May 25, 1922, when ten years old. All the piers cast within the cofferdam appeared in first-class condition. Those cast between tides showed some signs of deterioration below high tide line.

In 1902 a series of specimens was made to test the protection from corrosion of steel by concrete. Concrete was mixed 1 : 3 : 6 with the expectation that it would be porous. The blocks were 4 in. square and 12 in. long, and had a ½ in. sq. twisted steel bar 16 in. long

Crushing Load on Sea Water Test Specimens.

No. of Piece.	Original Cross Section, Inches.	Area, Sq. ft.	Length Test Specimen, Inches.	Actual Section, Inches.	Total Load, Pounds.	Load, Sq. in. Actual Section.	Ratio Strength Top to Bottom.
7 Top	$15\frac{7}{8} \times 16\frac{9}{16}$	1·82	$15\frac{1}{2}$	57·3	157,300	2,750	·82
7 Bottom	$15\frac{7}{8} \times 16\frac{9}{16}$	1·82	$35\frac{1}{2}$	231	778,800	3,375	
11 Top	$16 \times 16\frac{3}{4}$	1·86	36	236	750,200	3,180	·93
11 Bottom	$16 \times 16\frac{3}{4}$	1·86	37	240	823,900	3,435	
22 Top	$15\frac{7}{8} \times 16\frac{3}{8}$	1·80	$30\frac{3}{4}$	207·5	463,100	2,235	·92
22 Bottom	$15\frac{7}{8} \times 16\frac{3}{8}$	1·80	36	212·5	562,100	2,645	
23 Top	$16\frac{3}{16} \times 16\frac{1}{4}$	1·82	$32\frac{1}{2}$	226·5	391,600	1,730	·91
23 Bottom	$16\frac{3}{16} \times 16\frac{1}{4}$	1·82	$33\frac{3}{4}$	222·5	424,600	1,907	

It will be noted that the normal mixture of concrete shows as good results as could be expected of any concrete of this mixture and age. It will be noted also that the bottom end of each of the four tests is stronger than the top ends. Omitting No. 7, where a small sample only could be tested and therefore may not be directly comparable with its own bottom, the other three show a ratio of strength of top to bottom of about 92 per cent., which indicates that there is a common law as to the condition of the concrete when permanently wet as compared with dry.

In 1912 the author built a fish pier in Portland Harbour, consisting of a wharf supported by concrete piers about 4 ft. square with a heavy floor above forming the wharf platform, on which a fish house was built. Most of the piers were built inside a cofferdam, and were therefore cast dry and allowed to set for over a

running through the centre and projecting at both ends. One series of these was immersed in sea water, and after three years' testing a number of the specimens were lost. The second series was immersed in a trunk sewer. After seven years a number of the specimens were lost. The third set was buried in the ground, always damp, sometimes saturated with water, underneath where a waterspout from the roof of a building dripped. A specimen from this group after being twenty years in the ground was removed and split open. In every specimen of all three series, where the steel was in hard contact with the cement it came out bright ; where there were voids, there was rust. When the bars were originally imbedded they were coated with hard rust but no scales. This would indicate that cement will protect steel from corrosion in unfavourable conditions.

While it is not time to draw final conclusions from these series of tests, and while the series are not sufficiently comprehensive to prove a general rule for all cases of immersion of concrete in sea water, some conclusions are now justified, and might be helpful to those designing marine structures in the future.

First of all, it appears that the mechanical action of the elements is a much more vital point of consideration than chemical action. Those specimens which were most dense show the least sign of wear to-day. Those specimens which were built porous, with the expectation that they would soon disintegrate, have done so. Chemical action must be considered. The specimens made of cement low in alumina, both lean and rich mixtures, are in good condition and lead the series. Those which had foreign ingredients (Nos. 22 and 23), of hydrated lime and Sylvester solution, show serious weakness, while, on the other hand, one specimen containing 5 per cent. of clay as filler to make the concrete dense is still in good condition.

The question of the amount of water used in mixing must be considered. The condition of the specimens indicates that those containing 9 to 10 per cent. of water are in better physical condition than the very dry or very wet specimens.

In placing concrete in forms, if the workmanship is good, excess of cement and mortar is brought to the surface and produces a skin which resists sea water action very well until abrasion has removed it. The concrete below is not so durable in resisting wear as this skin.

The specimens which are made of the poorer materials which earliest fail due to tidal action, in their lower portions which are permanently immersed, have proved durable.

An explanation of the reason for the top end showing less strength than the bottom end may be partly due to the matter of suspension. In order to handle the specimens readily, ⅞-in. square steel bars were run the full length through two diagonal corners about 2 in. from the surface. A hole was cored in the centre of the specimen, and into this was grouted a hook with a shank about 3 ft. long by which the specimen was suspended. The dead weight of the specimen is first carried by the reinforcing bars, and in the upper 3 ft. the load is transferred through the mass of the concrete itself to the hook. This produces some tension in the top member equal to about 100 lb. per lin. in. of specimen in the upper 3 ft. This condition may have produced porosity, or cracks invisible to the eye, through which the specimen weathered. The top end was subjected to annual variations of temperature of probably 100 deg., and at times to changes of many degrees within a few hours, at times to a film of ice upon the surface, and to a slight degree of abrasion from floating objects in the water.

It seems safe to conclude that if rich concrete is made from a good quality of cement, normal composition, or low in alumina, and material is thoroughly mixed, using 9 to 10 per cent. of water and placed in the dry with careful workmanship, spading to assume a dense surface, we can be assured of durability in sea water unless there is a considerable amount of abrasion, in which case it will be a wise precaution to face the concrete within the limits of tidal rise and fall with a protective coating; and that below low tide, and at above high tide, concrete as above described is a practical, satisfactory and proper building material.

CONCRETE EXHIBITS AT THE ROYAL AGRICULTURAL SHOW.

A NEW TYPE OF TELEGRAPH POST.

CONCRETE was represented at this year's Royal Agricultural Show by Messrs. Tidnams, the well-known concrete specialists of Wisbech, whose stand included several new features, prominent among which was a reinforced concrete "Boom-type" telegraph post made on an entirely new design. The specimen exhibited was 30 ft. in length over all, and although reinforced weighed only 4½ cwt.

Most posts, such as telegraph, telephone, electric cable posts, and the like whose lengths exceed a limited number of diameters are subject to both axial and bending stresses—axial stresses from the superimposed weight of the wires and cables they carry, and bending stresses from the force of the wind against the post itself. The axial loads may in most cases be regarded as negligible compared with the bending forces, and the posts therefore become cantilever beams and must be designed as such.

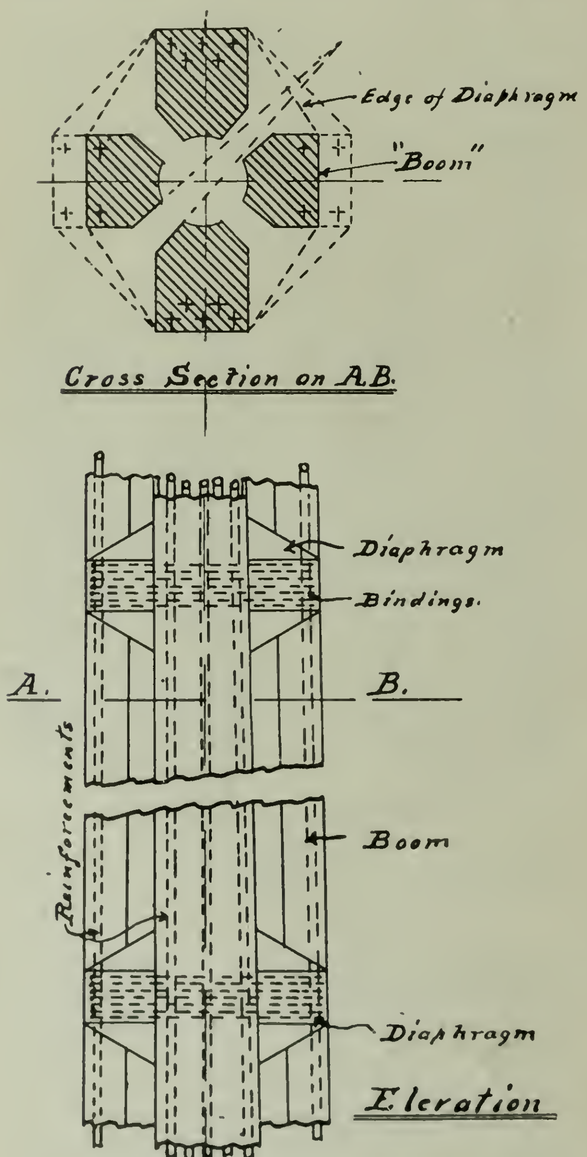


FIG. 1.—"BOOM-TYPE" TELEGRAPH POST, CROSS SECTION.

The general theory upon which the post illustrated herewith has been designed is as follows: Taking a square section as unity, by splitting that square through the middle in one direction (horizontal) and separating the divided pieces by a distance equal to their base a compound section is produced which, although the solid area is the same in both cases, yet in the latter the section modulus is greatly increased, and it does, in fact, enter the realms of the lattice girder, having two separate booms and practically no neutral axis. Each boom must then be either in tension or compression and practically under full load all the time so long as the stress remains unaltered.

Telegraph and other posts carrying overhead wires have very little pull on the sides in the direction of the line of the wires, and therefore not so much strength is needed in that direction. A fair margin has, however, to be allowed, and therefore side booms are introduced as well, as seen in the cross section (*Fig.* 1). If the overall diameters of the booms were alike, a great quantity of unnecessary material would be included for line posts, and the aim of the designer has been to cut down wherever possible. Terminal posts, however, have all booms designed alike so that they can take stresses from any direction. Usually, then, but not necessarily, the section resembles a hollow cross, the corner webs between the booms being cut away longitudinally for certain lengths for structural reasons and to eliminate weight.

The braces and ties in the figurative lattice girder are represented in this case by solid portions or diaphragms, forming square or octagonal parts which come at points every few feet along the length. At these points the reinforcing bars which run through the booms are securely fastened together by bindings, and in certain places they are welded together. The strength of the reinforcements and their sectional areas are calculated against the maximum bending moment at the spot chosen. The factor of safety is 3 unless otherwise required.

A "Boom-type" telegraph post and signal post are shown in *Figs.* 2 and 3.

This principle may be applied to railway signal posts, fence posts, supports for tanks—in fact, to posts of every description. The "Boom-type" post is the invention of Mr. F. W. Bradshaw of Messrs. F. W. Bradshaw & Co., Engineers, Hitchin, who is the patentee.

A trial test on one of the light pattern "Boom-type" telegraph poles was recently carried out. The pole was designed for a breaking load of 6 cwt. applied at a point 23 ft. above ground after a maturing period of 90 days. The trial was carried out on a "green" pole of only 30 days maturing, and that only to a point well within the elastic limit. A test to destruction is arranged for a date after 90 days maturing. Total length of pole, 30 ft., with four arms; depth in ground, 5 ft.; dimensions at ground line, 9 in. by 6¾ in.; dimensions at top for arms, 4 in. by 4 in.; weight of post, 6 cwt. 1 qr.

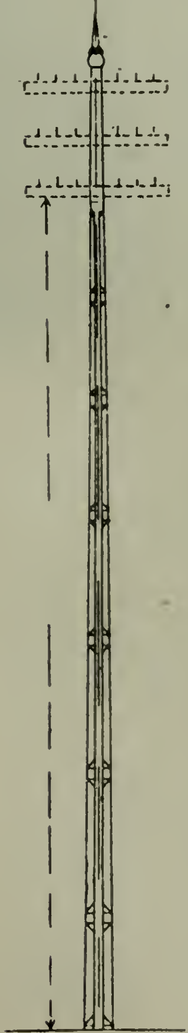


FIG. 2.—LIGHT "BOOM-TYPE" TELEGRAPH POST.

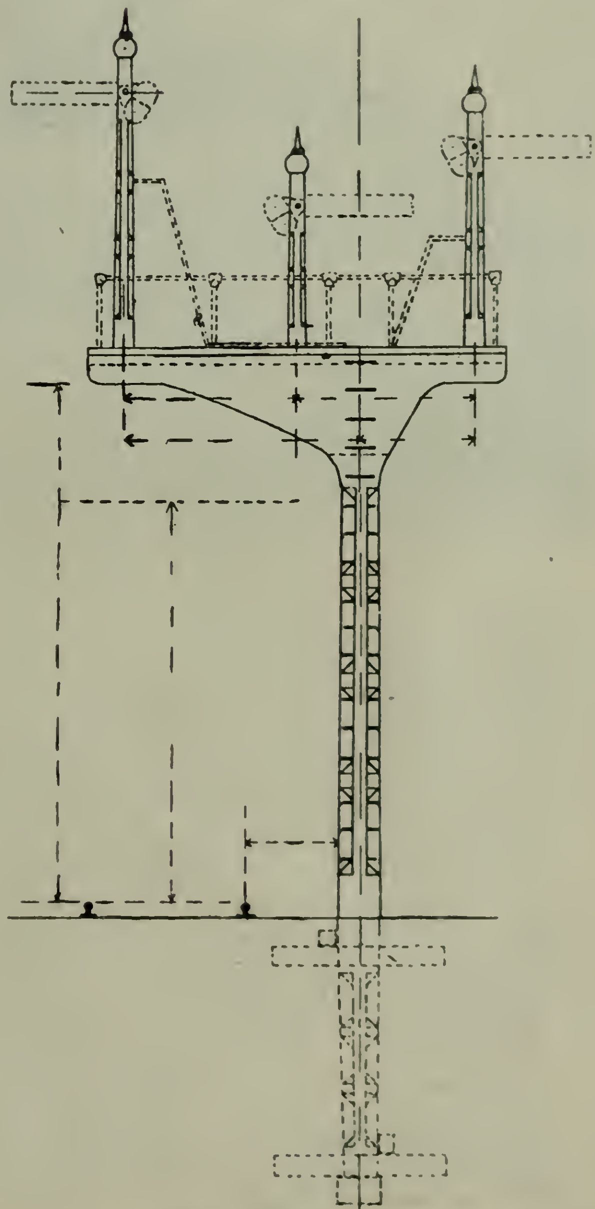
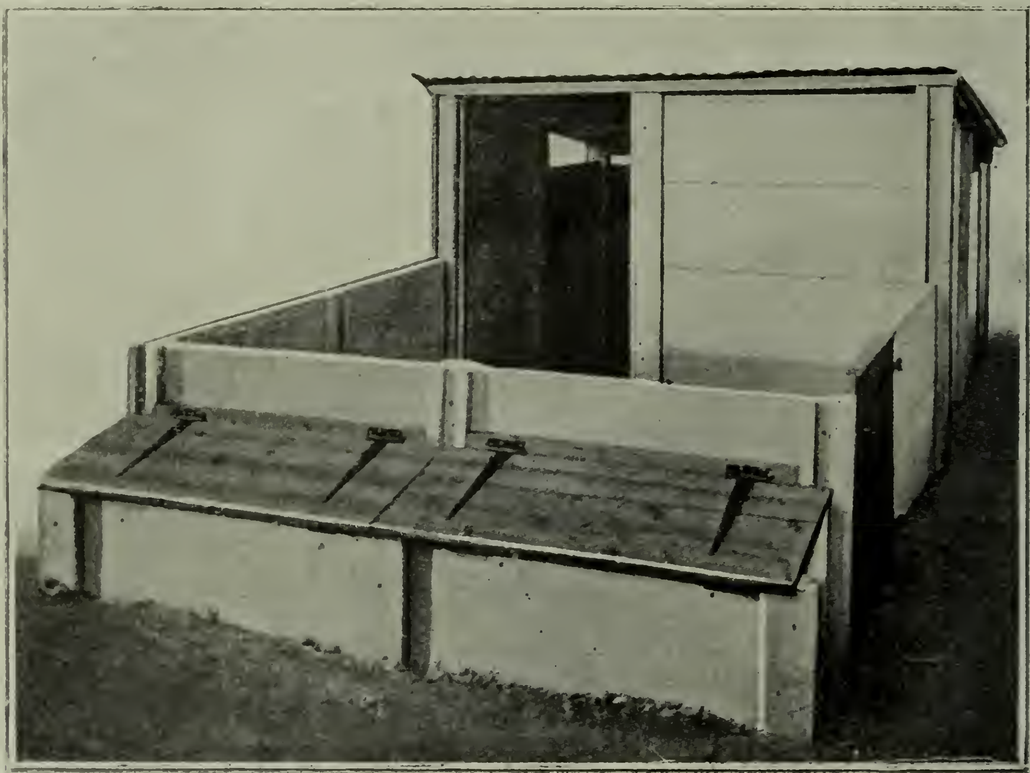


FIG. 3.—THREE-DOLL "BOOM-TYPE" SIGNAL POST: FRONT ELEVATION.

The load was applied at a point 23 ft. above ground in a line at right angles to the direction of the overhead wires, with the following results: Deflection at $1\frac{3}{4}$ cwt., hardly apparent; deflection at $3\frac{1}{2}$ cwt., about 18 in.; calculated yield point at 30 days, $4\frac{1}{2}$ cwt.; total load applied, $3\frac{1}{2}$ cwt. There was no apparent injury whatever. Every "boom" rang out clear and sharp both with load on and off. On removing the load the post returned to a perfectly upright position immediately.



CONCRETE PIGSTY AT THE ROYAL AGRICULTURAL SHOW.

AGRICULTURAL EXHIBITS.

Among the new features at this stand was a portable concrete pigsty, made of pre-cast members on the pier and slab principle. The posts are slotted on all four sides so as to allow extensions either way if desired. The slabs are grooved and tongued, and as they simply slide into the slots and fit together without being grouted the sty may be erected rapidly and with unskilled labour. The floor space is 8 ft. by 8 ft. for both pen and sleeping place; the trough is filled from the outside. A general view of the structure is seen in *Fig.* 4.

It is now possible to carry out in concrete an imitation of any real stone. An example of this work was on view in the form of two Roman Doric columns which presented the appearance of dressed Bath stone. The cost is but a fraction of that for real stone.

This firm had also on exhibition a concrete garage 19 ft. by 15 ft. This was constructed of $4\frac{1}{2}$-in. concrete blocks tongued and grooved, the walls being two blocks thick with breeze blocks on the inner side. This construction can be carried out either with or without a cavity. The floor is of concrete 6 in. thick.

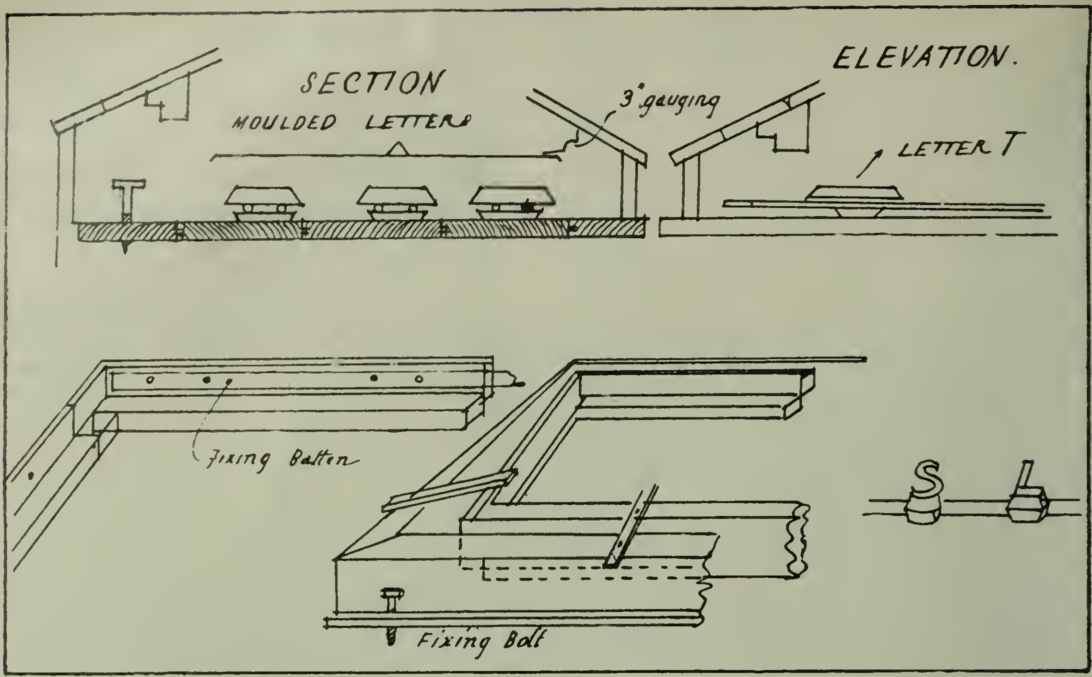
Other exhibits at this stand were pergola posts, balustrading, garden seats with ends of concrete and seat and back of wood, sundial, watering trough, paving slabs, small fencing posts for housing schemes, post and tube fencing for highways, rail and pale fencing, and a hand-carved specimen of a coat-of-arms.

CONCRETE NOTICE BOARDS.

EVERYONE is familiar with concrete posts for carrying notice boards, signs, directions, etc., but the use of concrete for the lettering is comparatively rare. The notice board illustrated herewith was erected at Swanscombe, Kent, nearly ten years ago, and is practically in the same condition now as when placed in position. In view of the permanence of this type of lettering, and the saving which it makes possible owing to the absence of the frequent re-painting necessary to keep painted signs legible or to prevent metal letters from rusting, it is probable there would be a good demand for concrete letters for outdoor signs if they were better known. To make different moulds for all the letters used in each notice would no doubt make the cost prohibitive, but there seems no reason why concrete notices should not be a commercial proposition if well-shaped letters were made on mass production lines and supplied to order, as is now the case with metal lettering.

The method of making the lettering for the sign at Swanscombe is illustrated herewith. A wooden mould was prepared, and ¼-in round reinforcing rods were laid on small concrete beds, measuring 2 in. by 2 in., and taking the shape of truncated pyramids, laid in the bottom of the mould. These small beds were moulded separately, and when in position carried the letters. After the beds were in position the mould was filled with concrete (3 parts sand to 1 part Portland cement) to the level of the rods. The letters, which were formed in small wooden moulds, were 1½ in. deep, and of a pyramidal shape in order to obtain a good key. When the letters were correctly set in their respective positions the mould was filled with a further ¾-in. depth of cement and sand

CONCRETE SIGN AT SWANSCOMBE.



METHOD OF CONSTRUCTING CONCRETE SIGN AT SWANSCOMBE.

grout, thus embedding the letters in the background for half their depth.

The necessary contrast between the lettering and the background was obtained by mixing ground-up old arc-lamp carbons with the cement used for the letters and by spreading a layer of broken and graded white marble chippings on the background, the effect thus being black letters against white.

After the notice and its background had set, the inner and outer bordering was moulded and placed in position. The interior moulds to form the border were made in pieces and screwed together so as to draw out easily (as shown in the sketch), thus enabling the mould to be taken out without damaging the border after it had set.

For fixing the notice to the posts, four bolts were cast in the mould so that the heads were in the thick bordering, and these were placed in holes sunk in the posts and screwed tight. The bolts were then cemented in the holes in the posts, and the back of the slab and the face of the posts were rendered with grout to prevent any possibility of the percolation of water separating the slab from the posts during frost.

Foundations For Concrete Road Reinforcement.

THE Bureau of Public Roads (United States Department of Agriculture) is undertaking experiments on a road in Washington. The road is being reinforced with many different arrangements of wire mesh and round steel rods embedded in the concrete. The joints will be either a crack left in the road, to be filled with tar, or a sheet of corrugated metal set on edge. Some sections are to have joints running along the middle of the road, some across it, and some will be built without joints. In the construction of ribbed sections, instead of placing the concrete on a nearly flat subgrade, trenches will be dug in the subgrade running parallel to the edges of the road and also across the road. These trenches will be filled with concrete, giving the slab downward projections of concrete and presumably strengthening it. Experiments will also be conducted to determine the strengthening effect of treating the earth under the concrete. On one section the earth for a depth of 6 in. will be mixed with cement, using 1 part of cement to 20 parts of earth. In some places where there is a grade a trench under the concrete will be filled with gravel. These trenches will slope toward the edges of the road and drain away any water that might otherwise accumulate under the surface.

CONCRETE TANKS FOR EGG PRESERVATION.

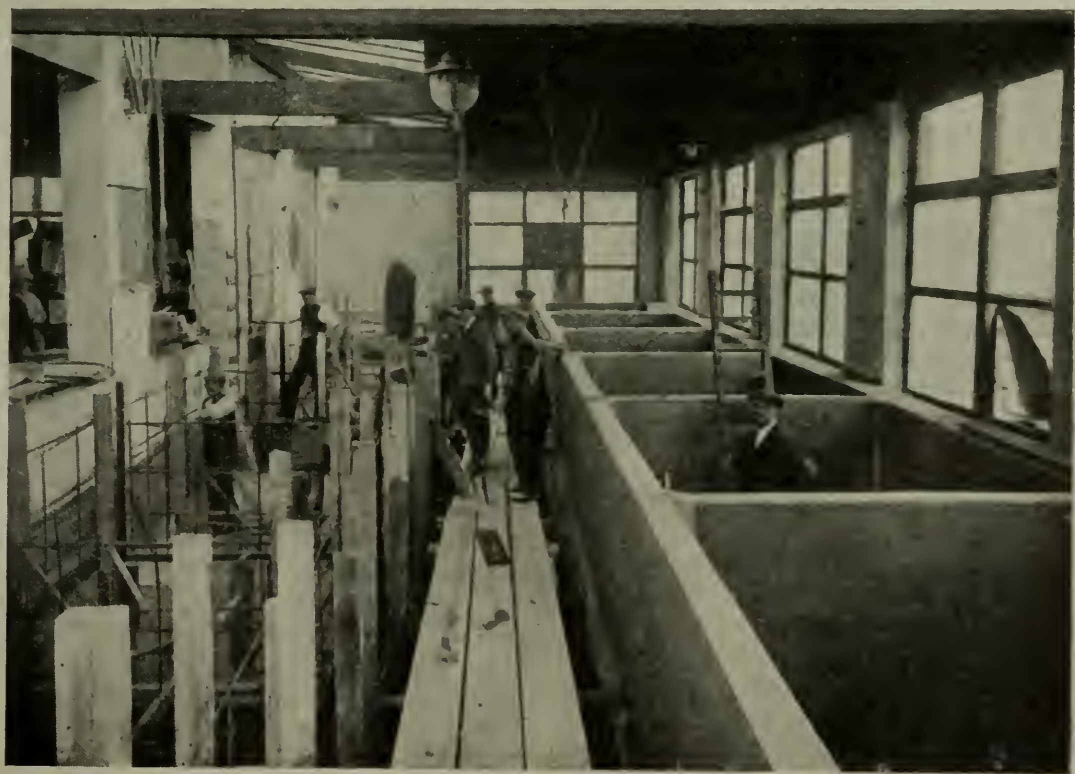
Remarkable developments have recently taken place in the egg-preserving industry, and in this connection we recently paid a visit to the headquarters of the Framlingham and Eastern Counties Co-operative Egg and Poultry Society, Ltd., at Ipswich. This society was founded in 1903, its object being the collection, preservation, and marketing of eggs, and the fattening of poultry. To-day it has over seventy depôts in the provincial towns and villages in East Anglia.

During the society's existence over 122 million eggs have been handled, twenty million having been collected last year alone. The eggs are stored in "pickle," contained in eleven concrete tanks each 8 ft. by 7 ft. and 7 ft. 6 in. deep, the reinforcement being supplied by the Trussed Concrete Steel Co. The thickness of the walls is 6 in., but on account of the softness of the ground on which the tanks were constructed the bottoms are 10 in. thick and additional reinforcement was employed. The aggregate was inland ballast screened through a $\frac{3}{4}$-in. mesh and afterwards through a $\frac{3}{16}$-in. mesh to remove excess of fine material. This was then washed and used in the following proportions: $3\frac{1}{2}$ parts coarse material, $1\frac{1}{2}$ parts sharp, washed sand, and 1 part Portland cement. All the wood forms were planed and, before use, were coated with linseed oil in order to prevent adhesion. This left a very clean job.

Each tank will accommodate from 115,000 to 140,000 eggs according to size, and the weight of the eggs in each tank is over eight tons. The tanks, which were filled three weeks after completion, have now been in use for over eleven months and are giving every satisfaction. The tank in which the "pickle" is mixed is also of reinforced concrete, elevated on concrete supports in order that the liquor may be automatically fed into the tanks.

All the work was carried out by Mr. Wesley Kenney, contractor, of Ipswich, to whose courtesy, and that of Mr. Warren (Secretary of the Society), we are indebted for these particulars, and for the photograph illustrating this article.

So far as is known, the only other instance of the use of concrete for this purpose in the United Kingdom is at Monaghan, Ireland. These tanks are four in number, each 15 ft. by 4 ft. by 5 ft. deep, the walls tapering from 5 in. at the



Reinforced Concrete Tanks for Egg Preservation.

bottom to 4 in. at the top, the bottom being 5 in. thick. The aggregate was clean washed gravel and sand, and used with cement in the proportion of 5 : 1. The walls and bottom are reinforced with No. 7 plain fencing wire 18 in. apart in both directions. After the tanks had been made a week, they were filled with water and kept full for a week, after which they were emptied and filled with "pickle" on April 1, 1921, and eggs were added day by day during the month. The eggs, to the number of twenty-four thousand dozen, remained in pickle until October, when they were removed in perfect condition and sold. This work was carried out by Mr. H. Skelton, Engineer, of Monaghan.

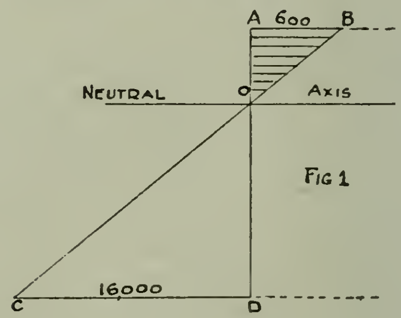
CORRESPONDENCE.

STRESSES ON HIGH-TENSION AND MILD STEEL.

Sir,—With reference to the communication in the September issue of your paper from the Managing Director of Messrs. Coignet, Ltd., in connection with the above, I think his idea of illustrating the effect of high-tensile steel as compared with mild steel by means of simple diagrams an excellent one—but certainly not by the diagrams reproduced, which are altogether misleading and suggest that he is labouring under the same illusion as the previous writer (Mr. Shelf), viz., that the modulus of elasticity has nothing to do with the position of the neutral axis.

His diagram is shown in *Fig.* 1, which clearly suggests that the ratio

$\frac{AO}{OD} = \frac{600}{1600}$, or, in other words, that the only factor which decides the position of



the neutral axis is the relation of the stress in the concrete to that in the steel, thus emphasising the very error requiring rectification. The correct diagram is shown on page 27 of *Reinforced Concrete Simply Explained.*

W. Y. Chamberlain.
Engineer's Department,
Harbour Office, Belfast.

WHAT IS THE USE OF THE MODULAR RADIO ?

Sir,—I have read with interest your abstract of the paper on "What is the use of the Modular Radio?" read by Mr. Dyson before the Concrete Institute, including the discussion, and would note that the following points seem to have been overlooked in the discussion.

1. Mr. Dyson's theory for unreinforced beams does not give approximate results for concrete beams, i.e.,

if $$x = \frac{f \text{ max}}{f \text{ min}} = 10$$

then $$Mu/Me = \frac{2 \cdot 712\ x}{x + 1} = 2 \cdot 46.$$

For triangular distribution, however,

$$Mu/Me = \frac{2\ x}{x + 1} = 1 \cdot 83,$$

which is very close to Feret's value of 1·89.

2. The neutral axis in beams 27 and 28 is practically identical for equal loadings. According to Talbot's parabolic theory the stress in the concrete in these beams is approximately 1,480 and 1,900 respectively, so it is possible that the difference is due to the steel not being strong enough in beam 27 to develop the full strength of the concrete. Variation in manufacture would also account for it.

3. *Fig.* 26 is disproved by *Fig.* 8; also in *Fig.* 26 the compression would not travel in a straight line but in a convex curve from end to end, and there would be a neutral axis above the steel.

4. On page 549 are given the results of experiments by Dr. Faber on single reinforced beams showing that the factor of safety increases with the percentage of steel, and Mr. Dyson claims that this

result supports his theory. From the context I infer that the factor of safety is based on the ratio of the ultimate load to the safe load calculated on the straight-line theory. The straight-line theory is not true at ultimate loads, especially with high percentages of steel. Talbot's parabolic theory should be used, when the 30 per cent. increase in the factor of safety for high percentages will practically disappear.

Again, on page 553 are given The Concrete Institute's tests; the steel stress calculated according to the straight-line or parabolic theory does not differ appreciably from Mr. Dyson's results, it being approximately 58,000, 55,000, 76,000, 79,000, 93,000 for A-B, C-D, G-H, J-K, and L-M respectively.

Mr. Dyson says (page 554) that "The stronger material gave the greater moment of resistance, just as in Professor Talbot's tests, for which the ordinary theory does not account." The ordinary theory does account for this. For ultimate loads these beams are all under reinforced (·7 per cent. to ·46 per cent.) and failure therefore occurs in the steel in every case; consequently the stronger reinforcement should and does give a greater moment of resistance because it can develop a greater stress in the concrete, which the concrete is quite capable of taking.

In under-reinforced beams the steel fails first; the moment of resistance is then less than the bending moment, and the beam collapses. The ultimate resistance of the steel is reached before that of the concrete; hence the addition of more steel or stronger steel will increase the ultimate moment of resistance.

The only difference between designing columns with a modular ratio of 15 and designing them for 600 in the concrete and 16,000 in the steel is to give columns designed by the latter method 10 per cent. more capacity for every 1 per cent. of steel. Hence the fact that such columns are satisfactory is no proof that the method of design is correct; they are only 10 per cent. to 20 per cent. overloaded, and this would not produce signs of failure.

I will not take more of your space. The absurdities of Mr. Dyson's method for reinforced beams are sufficiently dealt with in the discussion by Dr. Faber. In his interpretation of tests to suit his theory Mr. Dyson has not appreciated some of the above points. Mr. Dyson in his paper has conclusively proved the use of the modular ratio. In his attempt to do without it he finds that the neutral axis may be at the tension steel and sometimes even below it, which is an impossible condition. His assumption that the ultimate stresses in tension and compression are arrived at simultaneously is contradicted by his theory, which shows that beyond a certain percentage of steel there is no increase in strength.

H. M. GIBB,
(*Major att. R.E.*).

Simla.

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

HARDENING CEMENT AND CONCRETE.

Question.—We should be glad if you could give us any information regarding the hardening of cement (and concrete) by gauging it with water containing silicate of soda. Regarding the use of this chemical for rendering concrete floors dust-proof, we should like to know in what manner the silicate acts. Does it form a compound, with a constituent of the cement, or is its action merely physical?—T. B.

Reply.—When sodium silicate is used in connection with concrete work it is generally applied to the concrete after the latter has set. It is not desirable to mix the sodium silicate with the gauging water, because it is liable to cause the cement to become quick-setting. For application to concrete floors and other concrete surfaces a 10 per cent. solution is a convenient strength to use. The sodium silicate can be bought either in the solid form or in the form of the viscous liquid known as "water glass." It is believed that the sodium silicate has a chemical action, and combines with the hydrate of lime which is liberated when cement sets, so forming more of the silicate of lime which is the chief active constituent of cement.

BOOK REVIEWS.

THE RIEGER SLIDE RULE FOR REINFORCED CONCRETE REGULATIONS.

This is an extremely interesting and ingenious slide rule devised by Professor Rieger of Brno, Czechoslovakia ; its aim is to enable designers to make all the calculations involved in reinforced concrete design without reference to formulae or diagrams, and consists of a rule about 13 in. long and 3¼ in. wide provided on each side with wide reversible slides upon which are engraved a very large number of scales for use in the various calculations.

The first edition of the rule, which is the one under review, has, according to a pamphlet since received, been sold out and a second edition is now available containing certain detail improvements. The price of this new edition is given as £12, but it is not clear whether this includes the import duties payable under the Safeguarding of Industries Acts, although it is not clear what industries in this country are safeguarded by taxing the import of a device which is so full of complicated scales that it certainly would not pay any one to manufacture it here in view of the necessarily restricted sale.

In the pamphlet setting out the advantages of the rule it is stated that " one may use the rule in Great Britain as well as in France, in America or in Japan ; its use is unaffected by the variety of regulations." This is true for most of the scales because they are divided in terms of co-efficients which are mere numbers, but it is not clear how the use of the rule is unaffected by the variety of regulations since there appear to be—to mention one case—no scales which deal with the L.C.C. rules for the design of reinforced concrete pillars.

This rule is a very interesting instrument and will probably be found of great use by those designers who are able to probe its mysteries ; it enables calculations to be made which are now usually effected by the combined use of an ordinary slide rule and curve diagrams. The author suggests in his description that at present designers have to solve lengthy equations whereas every designer of the writer's acquaintance employs diagrams which eliminate these equations.

Our own inclination is against the use of complicated slide rules and in favour of the combination of the ordinary slide rule with the particular curves which one finds most useful, but this is of course a matter of personal taste.

It has to be acknowledged that, partly owing to the fact that the cursor was broken in the instrument when it reached us, the writer has not yet learnt to use it after one or two serious attempts ; this is probably largely due to the fact that the accompanying description, though lengthy and though the author was good enough to provide an English version of it, was not accompanied by diagrams sufficiently explicit to enable one to set the scale in accordance with the given directions.

E. S. A.

The Architect and Builder's Handbook. By the Late Frank E. Kidder.

London: Chapman and Hall, Ltd. 1907 pp. + xxiv. Price 40s. net.

" Kidder's Handbook "—hitherto defined as " Kidder's Pocket-Book "—is so well known that no special recommendation is necessary. It was first published nearly forty years ago, but the present volume, which is the seventeenth edition, has been considerably enlarged and revised by Mr. Thomas Nolan and a staff of specialist writers.

Several new chapters have been added in this present edition and many of the sections have been entirely re-written in order to bring the information in line with the latest research and practice. Among the new chapters added are " Specifications for the Steelwork of Buildings " and " Domical and Vaulted Structures," and these give some very useful information.

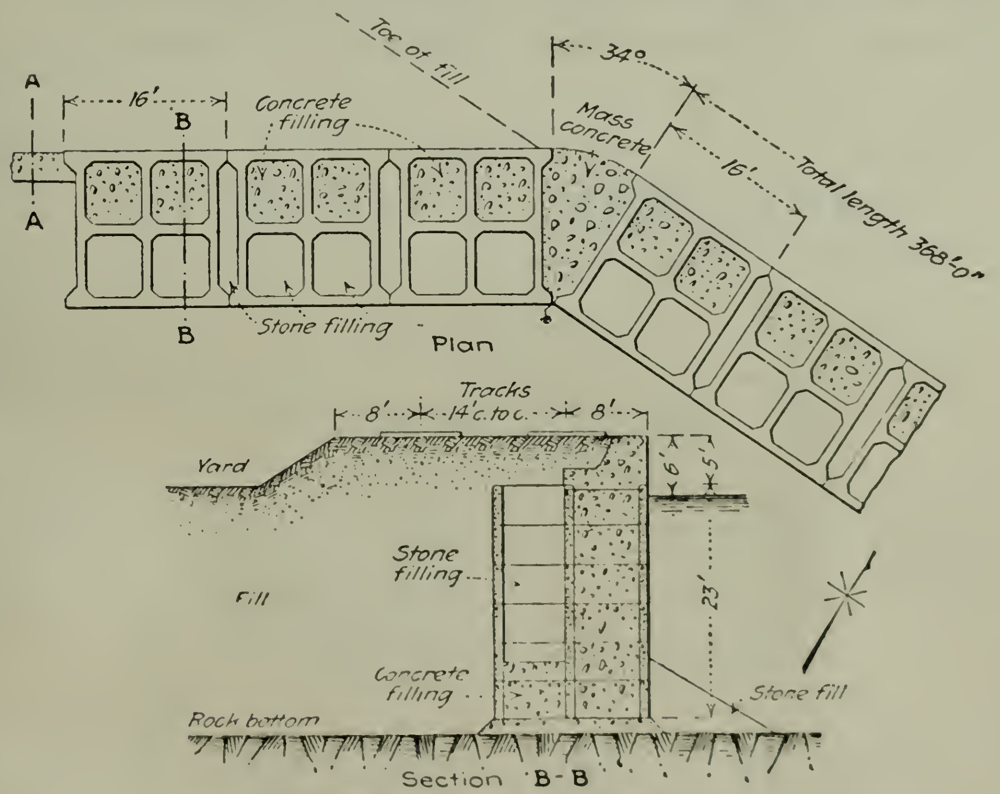
The specifications for steelwork are naturally based on American practice and the particulars given are therefore not applicable in all cases to work in this country. This fact must be borne in mind also when using the miscellaneous tables and information in the volume generally, as the liquid gallon in America is smaller than that in this country, and the ton is usually taken at 2,000 lb. unless specifically mentioned as a " long " ton. We were surprised to notice that in the list of architectural societies in Great Britain no mention is made of the Society of Architects, London, although the list is presented as a complete one, and practically all the provincial societies are given.

The volume contains such a large

amount of information that it is impossible to review the matter in detail, but it can be recommended as a useful book of reference for the architect and engineer when the reference is confined to general points which are not affected by the difference between the practice in America and this country. A. L.

HOLLOW CONCRETE-BLOCK DOCK WALL.

A novel method of erecting a large dock wall has been adopted at Petroskey, Michigan, by the Petroskey Portland Cement Co. The total length of the wall is nearly 400 ft., and, as shown by the illustration, it has been built of large cellular concrete blocks, each of which measures 16 ft. by 15 ft. on plan by 3 ft. 6 in. high. Each block is divided into four cells. The walls and partition are 8 in. thick, and the front and back walls extend beyond the side walls so as to form pockets between adjacent blocks. These pockets are filled with broken stone. There is no dovetailing or interlocking of the blocks, nor do they break joint, the wall being built up in 16-ft. lengths with vertical joints. In construction, the courses of blocks were lined up and secured



Hollow Concrete-Block Dock Wall.

temporarily by four $2\frac{1}{2}$-in. vertical tie-rods grouted into holes drilled in the rock and engaging holes in the corners of the blocks. At one point the wall makes a change in direction and the triangular space thus formed is filled with mass 1 : 2 : 4 concrete bonded to the wall by the flanges or projections on the face of the blocks. About 200 blocks were required and were made with a 1 : 2 : 4 mix with $1\frac{3}{4}$-in. stone for coarse aggregate. The concrete was poured in wood moulds and left for three days, after which the blocks were removed and stacked for thirty days to cure before being used. Each contains about 9 cu. yd. of concrete and has a weight of 36,000 lb. The blocks were placed in position by a 25-ton travelling crane. These particulars and the accompanying illustration are taken from a recent issue of *Engineering News-Record.*

MEMORANDA.

Professional Announcement.

A PARTNERSHIP has been formed between Mr. W. Cyril Cocking and Mr. A. C. Meston, and the firm of consulting engineers formerly known as "E. P. Wells & W. C. Cocking, Ltd.," will in future be carried on as "E. P. Wells, Cocking and Meston" at the same address, No. 10, New Square, Lincoln's Inn, W.C.2.

Reinforced Concrete Wireless Mast.

A WIRELESS mast, 664 ft. high, constructed of reinforced concrete, has, it is reported, been erected in Japan. The tower is about 55 ft. wide at the bottom and 5 ft. at the top.

Experimental Concrete Bungalow.

THE first of a number of concrete cottages which it is proposed to erect at Clitheroe has now been completed. It is of reinforced concrete cavity wall construction, and except for the slate roof concrete and cement is the only material used ; rainwater goods are of asbestos cement. The architects are Messrs. A. R. Gradwell & Sons, of Blackburn, and the contractors the Reinforced Concrete Constructing Co., of Manchester.

Safety of Buildings.

As an outcome of the recent Washington theatre collapse, the New York Section of the American Society of Civil Engineers has passed a resolution urging the desirability of the Society exerting its influence for such reforms in building laws and engineering practice as would make it impossible for any building in New York where public safety is involved to open its doors to public use until its safety and stability have been certified by a competent structural engineer.

A Use for Concrete Barges.

A FLEET of twelve reinforced concrete barges built by the United States Government during the war, and now surplus to requirements, is being put to good use on the Mississippi River. The barges, which are 226 ft. long by 36 ft. wide, are being adapted for various purposes. In one case two barges have been connected together and used as a foundation for a floating warehouse. In other cases they are being used as bases for floating cranes.

The Life of Concrete Roads.

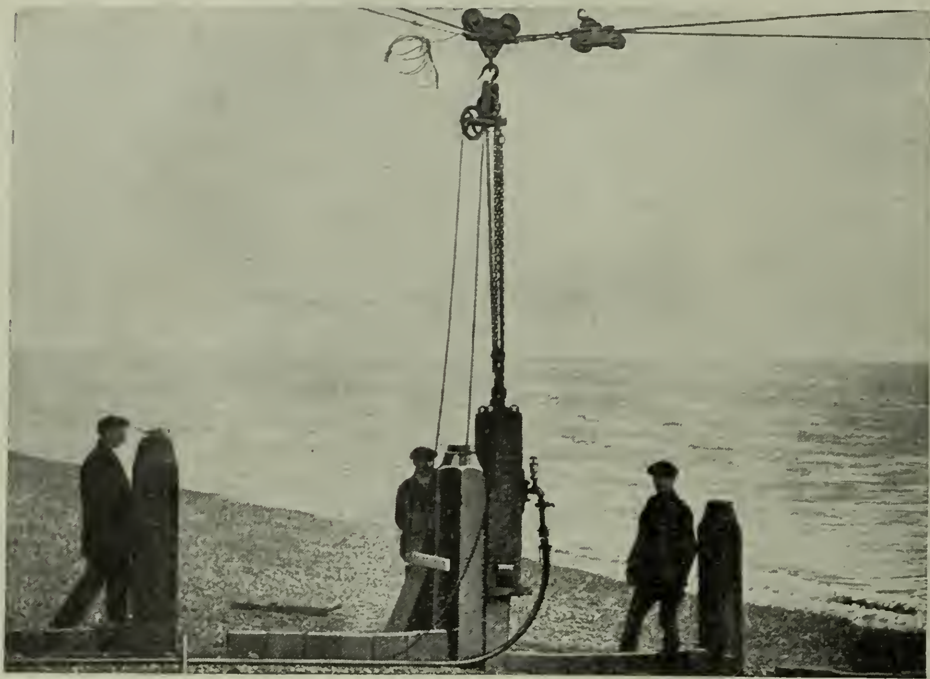
ONE of the oldest all-concrete roads in the United States—Woodward Avenue, Detroit, built thirteen years ago—has been broken up to make way for a wider road. The Chairman of the Road Commissioners who were responsible for the road, writing in an American contemporary, says the road has fully justified the hopes of the Commissioners, and judging from a photograph of the road taken just before its destruction, there were still many years of useful life left in it.

Rapid Concrete Road Construction.

WHAT is considered to be a record for road building in British Columbia has recently been accomplished in the construction of two miles of concrete roadway between Langley Prairie and Murray's Corner. On July 4 paving was started and on August 8 the last batch of concrete was poured. Materials used in the construction of the road were never placed on the subgrade, being conveyed on auto-trucks from the bunkers in batch boxes, thus ensuring clean aggregates. Grading was carried ahead of the work by a new type of machine.

Cement Pipe Joints.

THE following method of cementing pipe joints is stated to have proved very successful in America, and is being used exclusively in many areas :—First quality medium-setting cement is used, mixed so dry that the impress of the hand will be left upon a small ball which will crumble when let fall from a height of 12 in. The pipe should be laid upon a firm foundation ; the spacing of the spigot in the bell may be effected by placing a small bit of lead under it. A small bit of yarn should be used, just sufficient to keep the cement from entering the pipe. After filling the bell with cement it is thoroughly compacted with a yarning iron, by hand. This will have to be repeated two or three times before the face of the joint can be properly smoothed and rounded.



A No. 5 Hammer driving timber piles at Hythe, suspended from a cable.

The McKIERNAN-TERRY Double-Acting Automatic Pile Hammers

*are to pile driving operations what oxygen is to the air— they put **life** and **go** into the job.*

They hold the WORLD'S RECORD FOR FAST DRIVING, being at least 33% quicker than any other hammer.

¶ The range of sizes in which these hammers are made, from the smallest to the largest, the 11 B, offer the most suitable hammer for every variety in pile driving conditions.

They may be employed in situations in which no other hammer could be used.

With our piling, and with our standard pile driving equipment fitted with these hammers, you have the most perfect pile driving plant obtainable.

Ask for Catalogue No. 81.

THE BRITISH STEEL PILING CO.

DOCK HOUSE, BILLITER ST. LONDON, E.C.3. *Works:* CLAYDON, SUFFOLK.

In Portland, Oregon, approximately 27·8 miles of 4- to 16-in. pipe with cement joints have been laid, besides which about 4,000 ft. of 24- and 30-in. pipe has been relaid with cement joints. It recently became necessary to raise 100 ft. of 16-in. pipe which had been laid with cement joints. This pipe was raised approximately 4 ft. under full working pressure of about 70 lb. without any leaks resulting.

Visit to Portland Cement Works.

A PARTY of over sixty members of the Architects' and Surveyors' Assistants' Professional Union recently visited the Swanscombe cement works of Messrs. J. B. White Brothers. The whole process of cement manufacture and testing was shown and explained by competent guides, and formed a most interesting afternoon to a body of men whose work brings them so much into touch with the material. Much interest, also, was taken in a 250 ft. reinforced concrete chimney shaft, which had been erected in a fortnight. At the conclusion of the inspection a hearty vote of thanks was passed on behalf of the party to the officials of the company and to the guides.

PROSPECTIVE NEW CONCRETE WORK.

ANDOVER.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application to borrow money for the extension of the sewage disposal works.

BARNSTAPLE.—*Promenade.*—The T.C. has applied for sanction to borrow £6,000, for demolishing old buildings in the Strand, and for the construction of an ornamental river walk.

BATLEY.—*Sewage Works.*—The Ministry of Health has given its sanction to the General Works Committee to borrow £20,365 for sewage works extensions.

BLETHERSTONE.—*Bridge.*—The Narbeth R.D.C. has decided on the construction of a new bridge at Bletherstone.

CLEATOR MOOR.—*Sewage Works.*—The U.D.C. has decided to apply to the Ministry of Health for sanction to borrow £10,000 in connection with the sewage scheme for the southern part of the district.

DOVER.—*Road.*—The Corporation has approved the construction of a 60 ft. road from Elms Vale to the centre of Tower Hamlets at a cost of £18,000 and to complete the East Cliff Road at a cost of £43,000.

ECCLES.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the T.C. for sanction to borrow £16,500 for the extension and improvement of the sewage disposal works.

FRYSTONE.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Pontefract R.D.C. for sanction to borrow £18,500 for sewerage and sewage disposal works.

GORLESTON.—*Bandstand, etc.*—The Great Yarmouth Corporation General Purposes Committee has under consideration the construction of an amphitheatre in Gorleston Cliffs with a bandstand in the centre and concrete gradings for garden chairs and two terraced promenades. The cost is estimated at £14,700.

GRANTHAM.—*Bridges.*—The T.C. has instructed the Borough Surveyor to reconstruct with reinforced concrete two bridges over the river Witham.

GREAT YARMOUTH.—*Road.*—Instructions have been given to the Surveyor to proceed with the construction of a new road from Barnard Avenue to the race enclosures.

HERTFORD.—*Bridge.*—The Corporation has agreed to spend a further £540 on the scheme for bridging the river Beane. New foundations will be made with concrete slabs.

HUDDERSFIELD.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £133,300 in connection with the extension of the sewage disposal works.

LONDON (Clapton).—*Grand Stand.*—The shareholders of the Clapton Orient Football Club are considering a scheme of alterations and improvements to the grand stand and ground. It is proposed to remove the present stand, and to erect a steel and concrete stand with concrete terraces in the enclosure.

MARSKE.—*New Road.*—The Guisborough R.D.C. has instructed its surveyor to prepare plans for the extension of the projected trunk road from Middlesbrough to Redcar through Marske.

PONTYPOOL.—*Road.*—The Ministry of Transport has approved a scheme for the construction of a new road from George Street to High Street, Pontypool, at an estimated cost of £5,995.

PORTSMOUTH.—*Quay.*—The Corporation has decided to apply to the Ministry of Transport for sanction to a loan in connection with the proposed construction of a new reinforced concrete face to the quay. The estimated cost is £8,000.

PRESTON.—*Harbour Works.*—The Corporation is considering a proposal by the Ribble Navigation Commissioners to extend the river walls for a mile and a half beyond the present termination. A pre-war estimate of the cost was £77,000.

SKEGNESS.—*Sewage Works.*—A resolution

was passed at the last meeting of the U.D.C. urging the Ministry of Health to hold an inquiry into the proposal of the Council to spend £16,500 on the enlargement and modernisation of the sewage disposal works.

SOUTHREY.—*Bridge.*—The Lindsey C.C. has submitted a report to the Branston R.D.C. of a conference on the proposed erection of a ferro-concrete bridge at Southrey.

STANLEY.—*Bridge.*—The Stanley (Durham) U.D.C. has approved plans submitted by the Burnhope Colliery Co. for a new bridge on Burnhope Bank Top.

STOKE-ON-TRENT.—*Sewage Works.*—The Corporation has been advised to submit the following schemes to the Unemployment Grants Committee:—New sewage disposal plant, £15,000; extension to the Burslem sewage works, £20,000; River Trent improvement at Hanley sewage works, £6,000; new sewage disposal works at Trent Vale, £180,000.

SUNDERLAND.—*Sea Wall.*—The Corporation has received sanction from the Ministry of Health to borrow £10,500 for the extension of the sea wall and promenade at Roker.

WARDSEND.—*Road.*—The Corporation has decided to start constructing the new road from Wardsend to Pitsmoor. The estimated cost is £80,000.

WIMBLEDON.—*Sewage Works.*—The T.C. has decided to apply to the Ministry of Health for sanction to borrow £10,000 in connection with the sewage disposal works.

WORKINGTON.—*Dock Works.*—It is stated the Treasury has granted a loan of £500,000 to the Workington Harbour and Dock Board for extending, deepening, and widening Lonsdale dock, constructing a turning basin, and building a swing bridge.

TENDERS ACCEPTED.

BAMPTON.—*Reservoirs.*—The U.D.C. has accepted the tender of Messrs. T. Heale and G. Davey, of Bampton, at £2,695, for works including the construction of two covered concrete reservoirs with a combined capacity of 100,000 gallons.

BARNSTAPLE.—*Road.*—The T.C. has accepted the tender of Messrs. Campbell, Kenyon & Co., of Acton, at £2,702 15*s.* 8*d.*, for the reconstruction of Mill-road in reinforced concrete.

BARRY.—*Shops.*—The U.D.C. has accepted the tender of Messrs. L. G. Mouchel & Partners, at £7,500, for the erection of ferro-concrete shops and shelter at Barry Island.

FARNBOROUGH.—*Bridge.*—The U.D.C. has accepted the tender of Messrs. Parker & French, of Great Poulteney Street, W.1, at £1,675, for the widening of a brick arch bridge together with concrete foundations, and incidental road work, at Lynchford Road, Farnborough.

GLEMSFORD.—*Bridges.*—The West Suffolk C.C. has accepted the tender of Mr. R. J. May, Trowse, Norwich, at £994, for the reconstruction of "Scotchford Bridge," and the tender of Messrs. Maidwell & Co., Ltd., Great Finborough, Stowmarket, at £274 7*s.* 5*d.*, for the reconstruction of "College Bridge," both in reinforced concrete.

HULL.—*Electricity Works.*—The T.C. has accepted the tender of Messrs. A. J. Dorneley & Son, Ltd., at £7,908 15*s.* 11*d.*, for the ferro-concrete work in connection with the electricity works extension.

LITHERLAND.—*Sewer.*—The U.D.C. has accepted the tender of the Unit Construction Co., of Liverpool, at £1,674 0*s.* 6*d.*, for the construction of a 30-in. diameter reinforced concrete pipe sewer.

MANCHESTER.—For the erection of a warehouse, garage, and office in reinforced concrete at Trafford Park, Manchester, for Messrs. Richard Johnson, Clapham & Morris, Ltd., Lever Street, Manchester. Mr. Arthur Clayton, M.S.A., architect, Duchy Chambers, Clarence Street, Manchester, and 6, Chestergate, Macclesfield.

	£	*s.*	*d.*
James Byrom, Ltd.	31,531	0	0
Wm. Townson & Sons, Ltd.	33,990	0	0
Sir Wm. Arrol & Co., Ltd.	34,435	14	10
Tinker & Young, Ltd.	34,446	0	0
W. Storrs & Sons & Co., Ltd.	34,599	0	0
Russell Building & Contracting Co., Ltd.	34,599	0	0
J. Hollinsworth & Sons.	34,740	10	0
Leonard Fairclough, Ltd.	34,771	9	9
S. Megarity & Co.	35,393	0	0
F. Butterworth	35,414	0	0
Eatock & Co.	35,517	15	5
J. Gerrard & Sons, Ltd.	36,109	0	0
S. & J. Smethurst, Ltd.	36,163	0	0
Sir Robert McAlpine & Sons	36,690	0	0
Robert Carlyle & Co., Ltd.	37,012	0	0
C. H. Normanton & Sons, Ltd.	37,419	0	0
Moston Brick & Building Co., Ltd.	37,500	0	0
Smith & Briggs, Ltd.	38,159	0	0
Somerville & Co.	39,650	0	0
Arthur Fenton	41,914	0	0
James Cocker, Ltd.	41,950	0	0
Fred Mitchell & Son, Ltd.	42,024	10	2
AMENDED TENDERS.			
Tinker & Young	31,058	0	0
Wm. Townson & Sons, Ltd.	30,325	0	0
*James Byrom, Ltd., Bury	28,303	0	0

*Accepted.

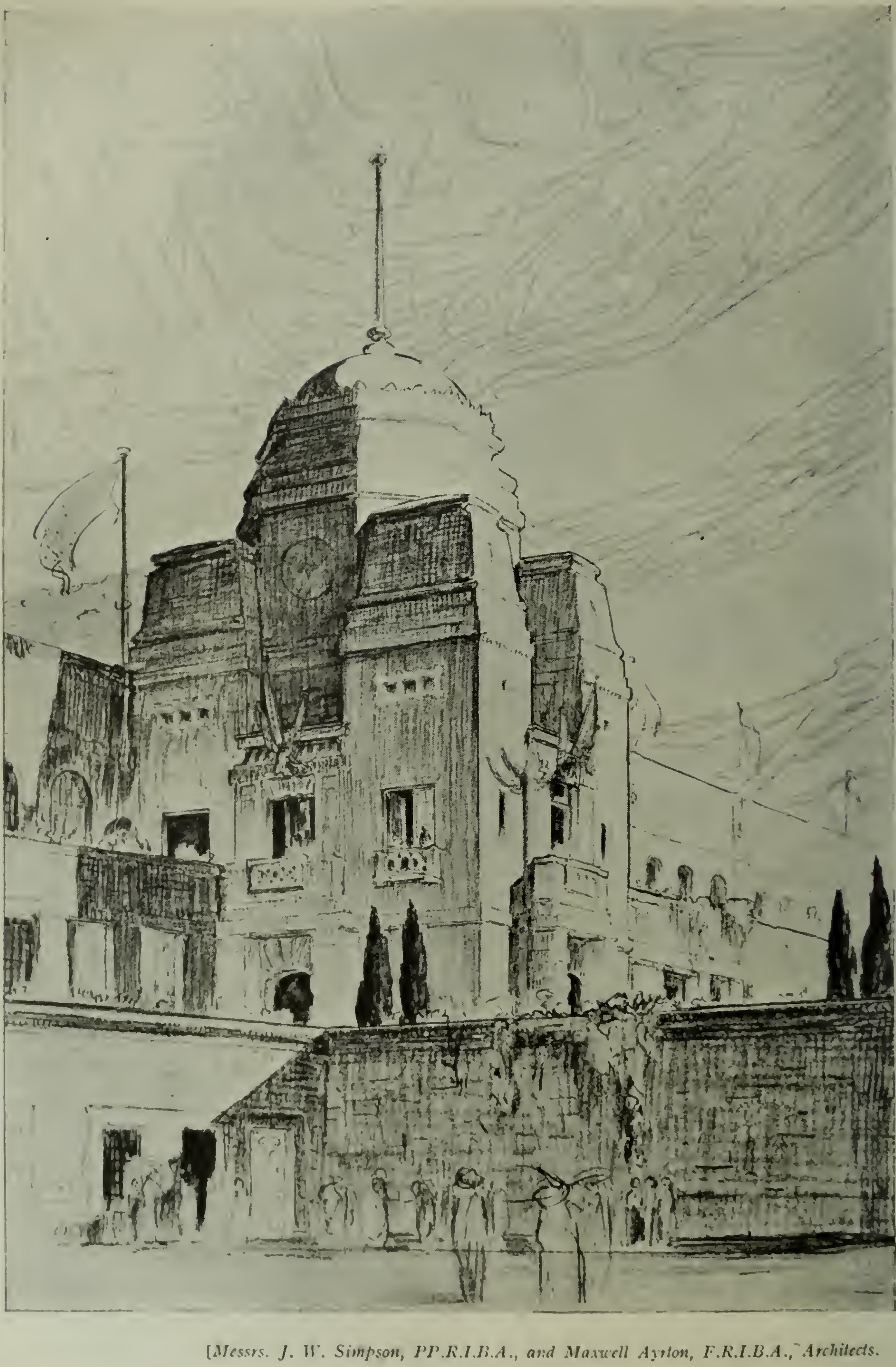
SALFORD.—*Electricity Works.*—The Corporation has recommended for acceptance the tender of Sir Robert McAlpine & Sons, Manchester, at £73,632, for the concrete and brick work in connection with the construction of the electricity generating station at Agecroft.

RECENT PATENT APPLICATIONS.

159,894.—D. Chioldi: Machines for moulding tiles and bricks.
164,730.—A. Areul: Fireproofing or waterproofing materials.
181,811.—Merz and McLellan and E. G. Weeks: Cement manufacture.
181,868.—W. R. Blackshaw: Moulding blocks and bricks of concrete.
181,930.—J. H. Walker: Concrete structures.
182,309.—J. Blunn: Moulds for making concrete blocks.
182,313.—A. L. Crane: Cement or concrete railway ties or sleepers.
182,821.—A. W. C. Schelff and F. Bradford: Reinforcement for concrete.
183,232.—J. A. Davies: Concrete blocks.
183,250.—H. Thompson and S. H. Thompson: Concrete construction.
183,307.—L. Shingleton: Adjustable forms and bearers for supporting shuttering for concrete floors and beams.
183,506.—J. McArtney: Method of securing cement or plaster facing to building-slabs, troughings, and to the coverings of girders or boilers.
183,509.—J. A. Malcolm: Building blocks.
183,546.—G. E. G. Leith: Reinforced block-work buildings.
183,548.—J. W. Davison and H. Bramwell: Concrete mixing machines.
183,615.—B. Morton: Revetments, groynes, foundations, and walls.
183,648.—J. K. Paton: Machines or moulds for concrete blocks.
183,737.—S. Anderson: Binding hollow walls.
183,764.—A. Auld and S. Niblock: Device for supporting staging from structural members.
183,949.—E. H. Arnold and A. W. Dixon: Measuring apparatus for use in the manufacture of concrete.
184,050.—H. J. Nowlan. Reinforcement for floor slabs and roads.
184,058.—R. Bloomfield: Moulds for building concrete structures *in situ*.
184,273.—A. H. Barnes: Concrete walls.
184,513.—L. T. Godfrey Evans: Submerged tunnels.
184,555.—W. Sykes: Manufacture of reinforced concrete articles.
184,561.—L. Alwyn: Buildings.
184,573.—J. T. McNay: Metal bonding ties for the bars of reinforced concrete structures.
184,584.—J. E. Wallis: Building blocks.
184,665.—F. Eckert: Hollow walls.
184,736.—V. Dorph: Walls.

TRADE NOTICES.

A torsion machine for wire, stated to be the first of its kind, has been put on the market by Messrs. Bruntons, of Musselburgh, and is the subject of an illustrated pamphlet issued by that firm. All sizes of wire up to $\frac{1}{4}$ in. diameter can be tested on this machine, which torsions the wire from both ends simultaneously at a regular and uniform speed. The torsions the wire stands before rupture are automatically recorded on a dial. It is stated that several of these machines can be manipulated by one operator. The total weight is 11 cwt., and a half-horse-power motor is sufficient for the drive. A bending machine is supplied by the firm for the purpose of preparing the test pieces.



[*Messrs. J. W. Simpson, PP.R.I.B.A., and Maxwell Ayrton, F.R.I.B.A., Architects.*

EASTERN TOWER, THE STADIUM.

BRITISH EMPIRE EXHIBITION, WEMBLEY. (*See p.* 699.)


CONTENTS
Vol. XVII. No. 11.
November, 1922.

CONCRETE AND CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 11. LONDON, NOVEMBER, 1922.

EDITORIAL NOTES.

CONCRETE AT THE BRITISH EMPIRE EXHIBITION.

PROBABLY because there are in this country but few large public buildings constructed of reinforced concrete, it is sometimes suggested that fine architecture cannot be carried out in this material ; at any rate, the absence here of monumental buildings of outstanding architectural merit built of concrete has always been felt by those who are convinced that, properly handled, concrete is as beautiful a material for building purposes as any other. It is, therefore, with particular pleasure that we reproduce in this issue some of the perspective drawings prepared by the architects for the huge Stadium now in course of erection at the British Empire Exhibition, Wembley Park. The large scale of the principal elevation of this building, the boldness of the two flanking towers, the massiveness of the retaining wall of the terrace and the flights of steps leading to it, are, considered separately, the very embodiment of the spirit of concrete, expressing the strength and durability of the material as emphatically, perhaps, as it is possible to do so ; yet by the able manner in which the parts have been balanced there is no suggestion whatever of dulness or overburdening weight in the composition as a whole. As is shown by the aerial perspective, the striking entrance elevation is continued on each side and right round the structure by well-proportioned arches supporting the stepping, and these give the whole *ensemble* an architectural character which could be imparted by no other material to a structure designed for such a purpose. The Stadium, commenced in March this year, is to be ready for the Cup Final in April next, and those responsible have no doubt that it will be completed within the short space of thirteen months. Good progress is being made, and as the shuttering is removed the building is revealing itself as quite up to the standard one is led to expect from the preliminary drawings and from such a well-known firm of architects as Messrs. John W. Simpson, PP.R.I.B.A., and Maxwell Ayrton, F.R.I.B.A., who are responsible for the whole of the Exhibition buildings. The retaining wall of the terrace is now clear, and from a short distance has every appearance of stone. This is obtained by breaking up the monotony such a large expanse of wall must possess by the use of shuttering which has left indented marks resembling the joints in stonework, and the stonelike effect is enhanced by the formation of buttresses, and voussoirs complete with keystones over the entrances. It might be objected by purists that it would have been better to have obtained the necessary relief by some other method than by giving it the semblance of stone, that the opportunity should have been seized of breaking up this surface with an ornamentation characteristic of and derived from the concrete itself. The use of stone and brick over a period of centuries has led to the adoption of styles for the respective materials which, evolved as they have been as the result of the method of trial and error and long experience, are now generally accepted. But reinforced concrete is a comparatively new material which has yet to form a tradition of its own, and the evolution of tradition in any building material has always been, and always must be, a long process if the result is to be sound. Although there is a much-felt need at the present time for a precedent in the design and adornment of concrete, it is impossible to lay down anything like a set of " rules of design " as can be done with materials of longer usage. That reinforced concrete will eventually evolve a tradition of its own is certain ; what form it will take only the future can tell, but we do not think designers in a material with such possibilities will be content to copy accepted methods in other materials. From a short distance this terrace wall has every appearance of having been built of blocks of stone ; to all intents and purposes it is a handsome and well-proportioned stone wall. In passing it would, however, be interesting to know the cost of this wall of poured concrete and compare it with the cost of a similar wall in stone.

But the Stadium is only one of the concrete buildings with which a large part of Wembley Park is destined to be covered within the next two years, and comparatively it is a small one, for the whole of the buildings are to be carried out in concrete. These buildings will cover a total area of over nineteen acres, and will form the largest collection of buildings of a permanent character, devoted to one object, in the world. The complete Exhibition is to be opened in 1924, and already the greater part of the concrete floors of the buildings are laid. We have not seen drawings of these buildings, but if one is to judge by a wood-and-canvas model of a section of the main building erected on the occasion of the recent visit of the Prince of Wales they will be as imposing and monumental in character as the Stadium. The choice of concrete as the material of construction has been governed by its suitability, its economy, and the speed with which it can be erected, and as these buildings will be visited by millions of people from all parts of the world they should be much more effective than any amount of printed or spoken words to convince the public of the possibilities of the cheapest building material when handled with care and understanding, and to dispel the fallacy that concrete is unsuitable for such important buildings. The Exhibition offered a great opportunity for a departure from more accepted methods in the design of the buildings, and the opportunity has, we think it will be admitted, been grasped to the full by the architects in the design of the Stadium. Some further particulars of the buildings are given on p. 699.

THE FIRE RESISTANCE OF CONCRETE.

THE inclusion of a paper on " The Resistance to Fire of Concrete and Reinforced Concrete," by Dr. F. C. Lea and Mr. R. E. Stradling, in the programme for the recent meeting of the British Association for the Advancement of Science is a sign of the times and another welcome indication of the application of science to an industry which has suffered in the past from rule-of-thumb methods. Our correspondence column shows that the conclusions reached by the writers of the paper on theoretical grounds are not acceptable to some who can claim to have much knowledge of the practical side of the subject, and we ourselves consider that the accumulated evidence from conflagrations clearly indicates that concrete buildings are more resistant to fire than buildings of other construction. The paper in question discusses from a theoretical standpoint the forces tending to disruption and disintegration that may be expected to arise when set cement and concrete are heated, and then proceeds to give results of observations upon the changes in dimensions, strength, and water content that occur when small specimens of set cement and concrete are heated in ovens and furnaces. The authors themselves have suggested that the conclusions on theoretical grounds may be rendered fallacious by reason of the unknown margin for movement of particles due to the porosity of concrete, and the fallacy is abundantly illustrated from the results of experiments that are recorded. Theoretically, concrete should break down on heating to 212° F., owing to contraction of certain of its constituents due to dehydration and expansion of other ingredients in accordance with their coefficients of expansion, whereas the results recorded in the paper show that concrete actually increases in strength with heating, in some cases up to about 572° F. In addition to this proved discrepancy between theory and laboratory results, we suggest that there is a further discrepancy between laboratory results and actual experience with buildings. The laboratory experiments were with briquettes of 1-in. section and cubes of 4-in. side, and the conclusions to which our correspondent takes exception are based on the heating of these small specimens in ovens and furnaces for periods up to 9 hours. Conditions such as these, where the concrete is heated on all sides, are obviously widely different from those that occur in conflagrations in buildings. These laboratory tests are in fact so divergent from actual fire conditions that we think it would be rash to accept the conclusions drawn from such experiments and ignore both the British Fire Prevention Committee's large-scale tests and the conclusions drawn from actual fire experience, both of which support the view that concrete is the best fire-resisting material known from a commercial standpoint. Upon the subject of the effect of heat upon concrete, the investigation has been useful and may lead to further improvements in the fire-resistance of concrete.

THE CORROSION OF IRON AND STEEL.

We have frequently in these columns pointed out the considerable saving in upkeep costs which can be made by using concrete in place of iron and steel, and are therefore interested to note the recent estimate of Sir Robert Hadfield that no less than 28,000,000 tons of steel are lost annually by corrosion. Taking steel at an average of £20 per ton, this loss amounts in the aggregate to the huge sum of £560,000,000 a year. In his presidential address to the Oil and Colour Chemists' Association last month, Dr. J. Newton Friend gave an instance of a firm in the Midlands which spent £10,000 a year on painting the exposed steelwork in its works and buildings, and the cost of preventive measures against corrosion cannot be less—and is probably more—than the loss due to corrosion which has actually taken place. The subject has, of course, been exercising the minds of scientists for many years, and is one of vital importance to the nation and might very well take a prominent place in the deliberations of those who are concerned to see that every avenue of wasted expenditure and effort is stopped in order that the finances of the country may once more be on a firm footing.

Until a positive preventative is found, and the recent invention of stainless steel offers some hope in this direction if it can be manufactured more cheaply than at present, concrete seems to be the only material which can fulfil practically all the functions of steel without the fear of corrosion and the annual expenditure entailed by the necessity for frequently painting iron or steel if it is not to rust.

In outlining some extensive experiments he had carried out at Birmingham and Worcester, Dr. Friend pointed out the disadvantage of linseed oil as a vehicle owing to the fact that it was slightly porous, and expressed the opinion that if linseed oil were heat-treated to get polymerisation it would be possible to reduce the porosity. In his experiments on the effect of the colour of the pigment on the durability of paint, he had found that in daylight the effect was different from that obtained in the dark; in the dark red, black and white pigments behaved similarly, but in daylight oxidation was much more accelerated in the case of white. From this he concluded that red or black pigments were likely to last longer than white. In the application of the pigment, he found that the best results were obtained with one thin coat and one thick coat of paint so far as the prevention of corrosion was concerned. Whereas, however, an increase of the total thickness of paint prevented corrosion of surfaces exposed to air, there was an optimum thickness of from 7 lb. to 9 lb. per 100 sq. ft., after which corrosion increased enormously in the case of sub-aqueous surfaces.

THE CONCRETE INSTITUTE.

As will be seen from the report in this issue, an extraordinary general meeting of the Concrete Institute held on October 19 confirmed the resolutions passed on September 28, by which the Concrete Institute is to become the Institution of Structural Engineers. In moving the principal resolution, Mr.. Wentworth-Sheilds set out the reason for the change; briefly it is that since its inception in 1908 the scope and activities of the Institute have covered a much wider field than is implied by its present title, and it is thought desirable that the name of the body should convey a more comprehensive and accurate impression of its membership and the work it is doing. While we shall be sorry to see the word "Concrete" disappear from the list of learned societies (and many of the members hold the opinion that it might with advantage have been retained in the new title), we wish the institution every success under its new name and in its extended field of activities.

THE BRITISH EMPIRE EXHIBITION.

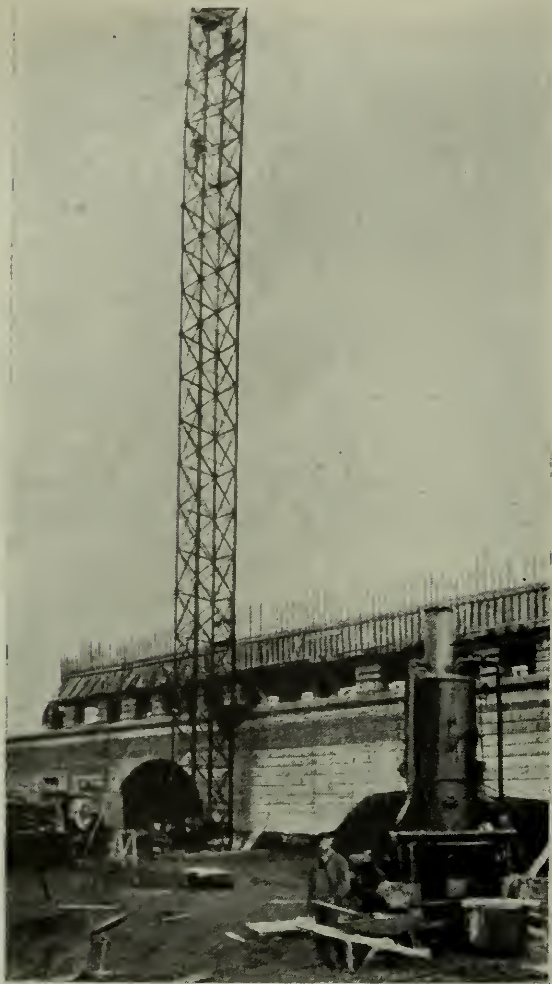
On January 10 last, H.R.H. the Duke of York cut the first turf in the work of transforming Wembley Park into a great Exhibition for furthering British trade. The main objects of the Exhibition are to place on show samples of the resources of the Empire and to demonstrate how those as yet undeveloped can be converted into wealth; to make the component parts of the Empire and their peoples better known to one another; to promote science, especially in relation to human well-being; and to enable established industries to exhibit their products and new industries to show of what they are capable. The site is one of considerable beauty, with a total area of about 130 acres, and is readily accessible from all parts of London.

The buildings are to be of a permanent character, and are to be completed ready for the opening of the Exhibition in 1924. In addition to the Stadium, there will be approximately nineteen acres of buildings, all of reinforced concrete. The largest will be devoted to British exhibitors, and each of the Dominion Governments and the Government of India will have its own pavilion.

The Stadium, which is being pushed forward as rapidly as possible in order that it shall be completed by April next

[*Messrs. J. W. Simpson, PP.R.I.B.A., and Maxwell Ayrton, F.R.I.B.A., Architects.*

East Tower and Terrace of the Stadium: British Empire Exhibition, Wembley.

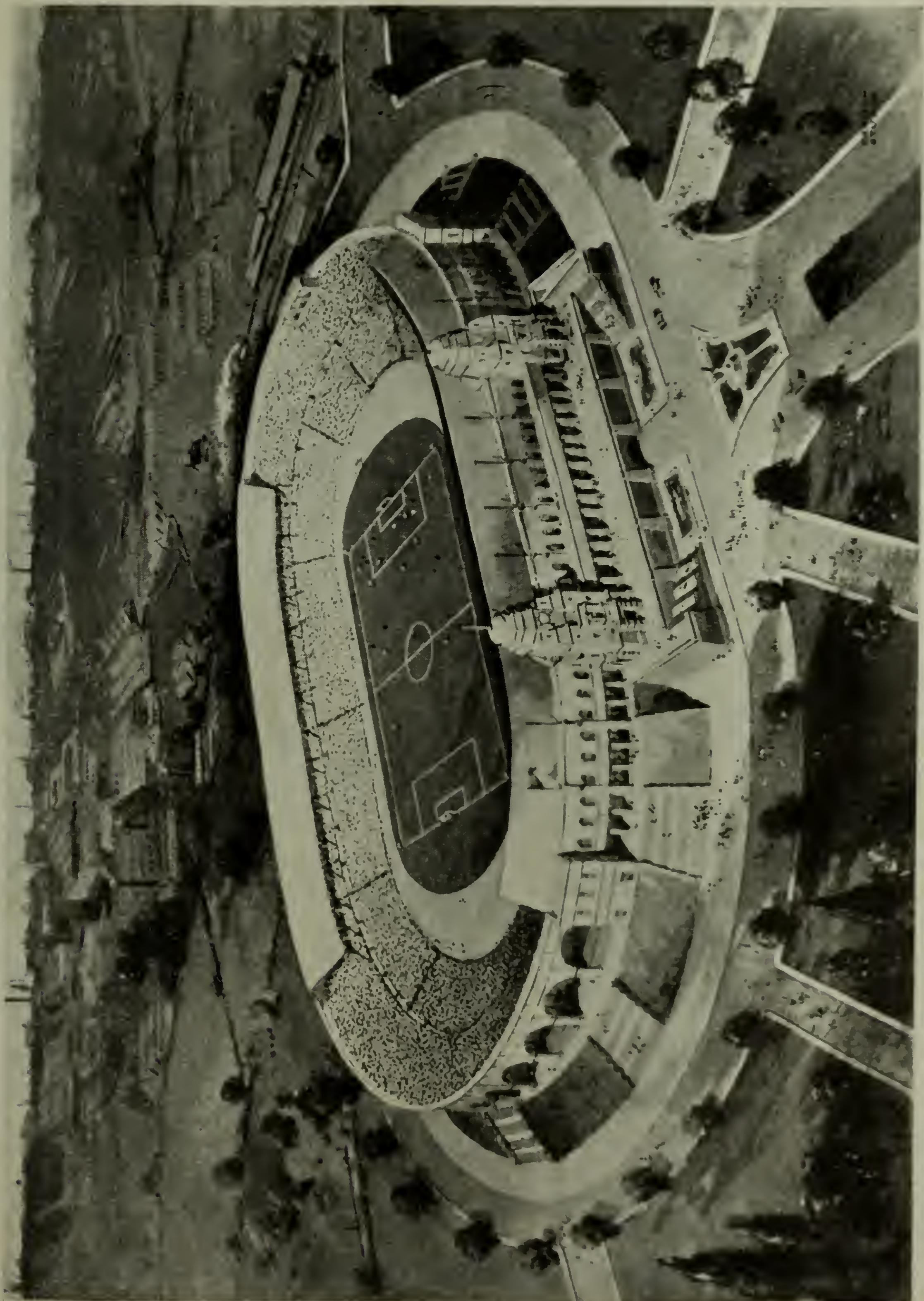


Chuting Plant at the Stadium: British Empire Exhibition.

for the occasion of the Final of the Football Cup Competition, is well shown in the illustrations in this issue, and is also referred to on p. 659. The structure has a capacity of 125,000 persons (33,000 seated and 92,000 standing), and will thus be one of the largest sports arenas in the world. An integral part of the Stadium will be a restaurant capable of seating one thousand persons, and large tea-rooms are provided behind the stands on the north and south sides. On the south side is also provided accommodation for five hundred competitors under the stand, and a gangway leads from these dressing quarters direct into the arena. The training quarters connected with the dressing-rooms will contain a gymnasium, plunge bath, recreation room, and offices. The design of the structure has been carefully considered so that a clear view of the field may be obtained by spectators in any part of the seating or standing accommodation. For convenience in filling and emptying the stand a roadway 40 ft. wide is provided for around the whole of the stand and under cover of the stepping.

The excavation of the site has been carried out with the aid of a drag-line excavator and a large steam shovel, and the earth from the centre has been thrown up to form the foundation of the lower half of the stepping, the upper half of which is supported on piers of reinforced concrete and steel lattice piers filled and cased with concrete. All the pouring is being done by an "Insley" distributing chute, the tower of which is 160 ft. in height. This plant consists of a heavy steel tower quickshift hoist bucket, having a capacity of 27 cu. ft. The sliding frame which carries the open steel boom, the 50 ft. boom section, and the 50 ft. counterweight chute section can be raised and lowered to any position required on the tower in about fifteen to twenty minutes. With this plant it is possible to place concrete within a radius of 100 ft. from the tower without supporting the chute sections from the ground, as these are carried by the boom. The plant represents the latest design of the Insley Manufacturing Company, whose European representatives are Messrs. Christmas, Hulbert & Walters, Ltd., of Caxton House, Westminster, S.W., by whom it is supplied. The large columns of the loggia on the terrace (illustrated on p. 703) were poured 3 ft. at a time. The great staircases at the ends of the terrace were poured *in situ*. In some parts the terracing is on made-up ground to a depth of as much as 20 ft., and here it is stabilised by sinking concrete piles. A large proportion of the concrete terracing for the seating is now finished; altogether the steps total about 15 miles in length. A considerable amount of the steps, girders, stanchions, roof trusses, etc., are being pre-cast on the site and hoisted into position after being left to cure for a fortnight. The roofing to the seats opposite the main entrance is of steel construction, which is to be covered with asbestos tiles. The reinforcement is being bent on the site. To facilitate entry and exit to the seats there are passageways leading from the roadway outside to the interior of the Stadium every 14 ft.; these may be seen in the illustration on p. 702. The exterior walls of the building, in addition to the stone-like effect indicated in the drawings, are being left from the forms with vertical corrugations forming semi-hexagonal flutes and ribs, about ¼-in. deep and 1-in. apart, not unlike tooling in masonry.

The main exhibition buildings cover an area of nineteen acres, and the flooring

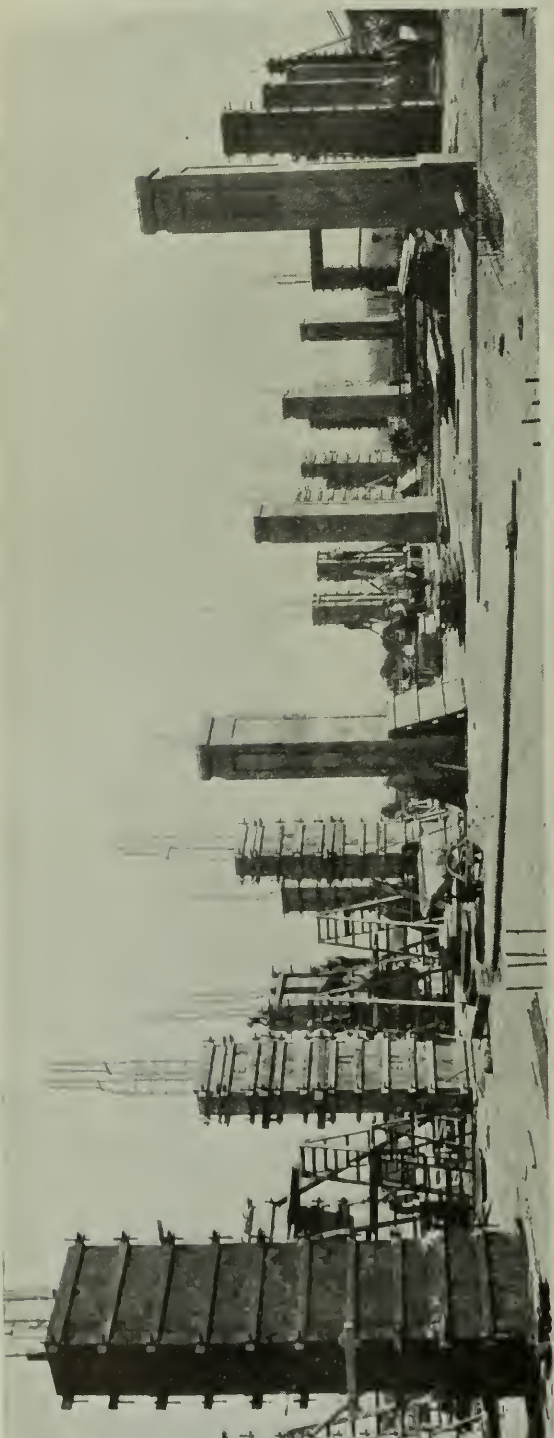


[*Messrs. J. W. Simpson, PP.R.I.B.A., and Maxwell Ayrton, F.R.I.B.A., Architects.*

THE STADIUM: BRITISH EMPIRE EXHIBITION, WEMBLEY.

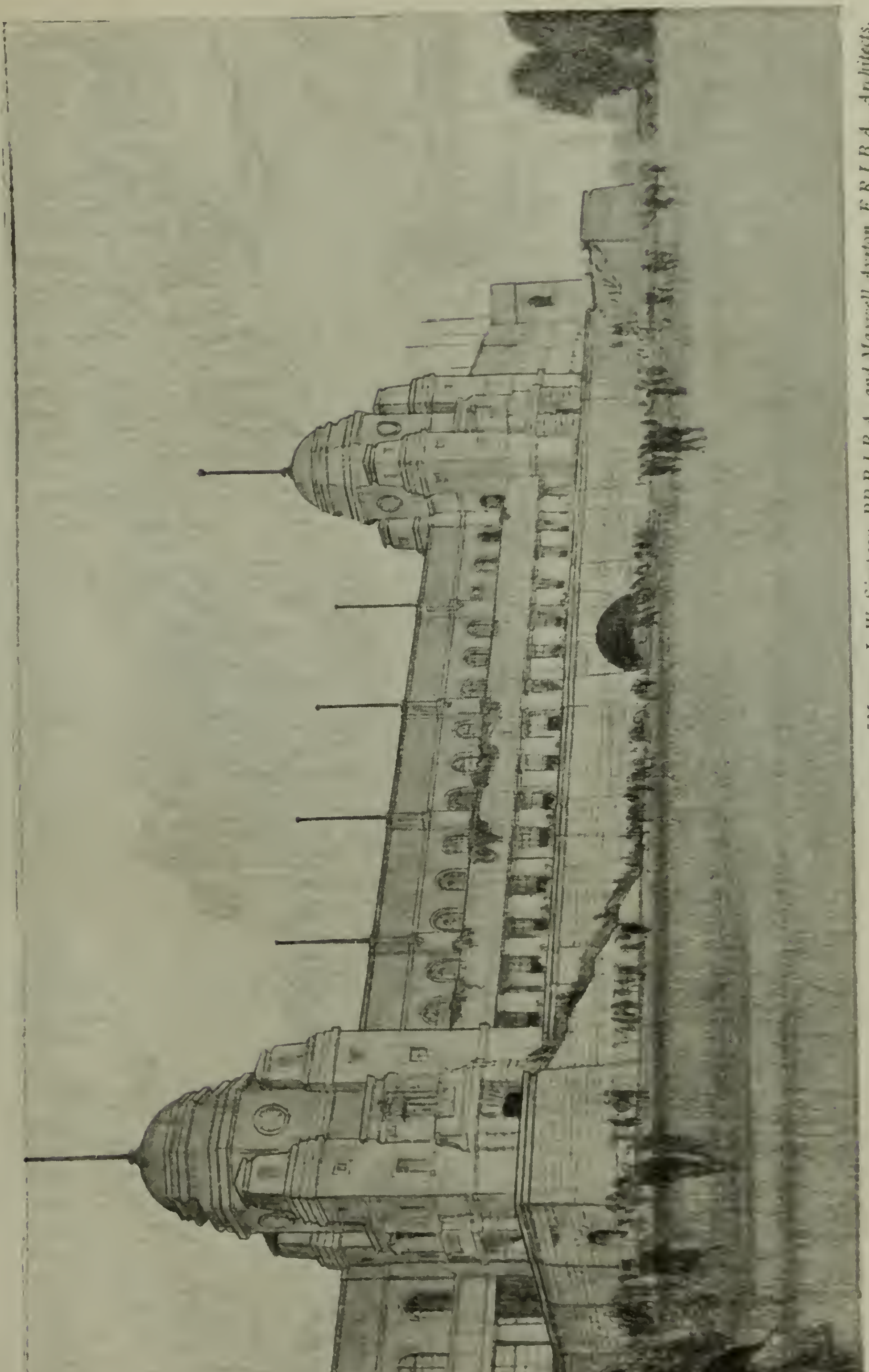
of this huge space has now been placed. The site required a considerable amount of levelling, and in order to stabilise the floor a number of brick piles were sunk in the made-up ground. On these piles were laid the reinforcing rods, and the concrete poured on top, in sections, to a depth of $4\frac{1}{2}$ in.

The architects for the whole of the buildings are Messrs. John W. Simpson, PP.R.I.B.A., and Maxwell Ayrton, F.R.I.B.A., and the consulting engineer is Mr. E. O. Williams, A.M.Inst.C.E. Sir Robert McAlpine & Sons, of Victoria Street, Westminster, London, S.W., are the contractors.



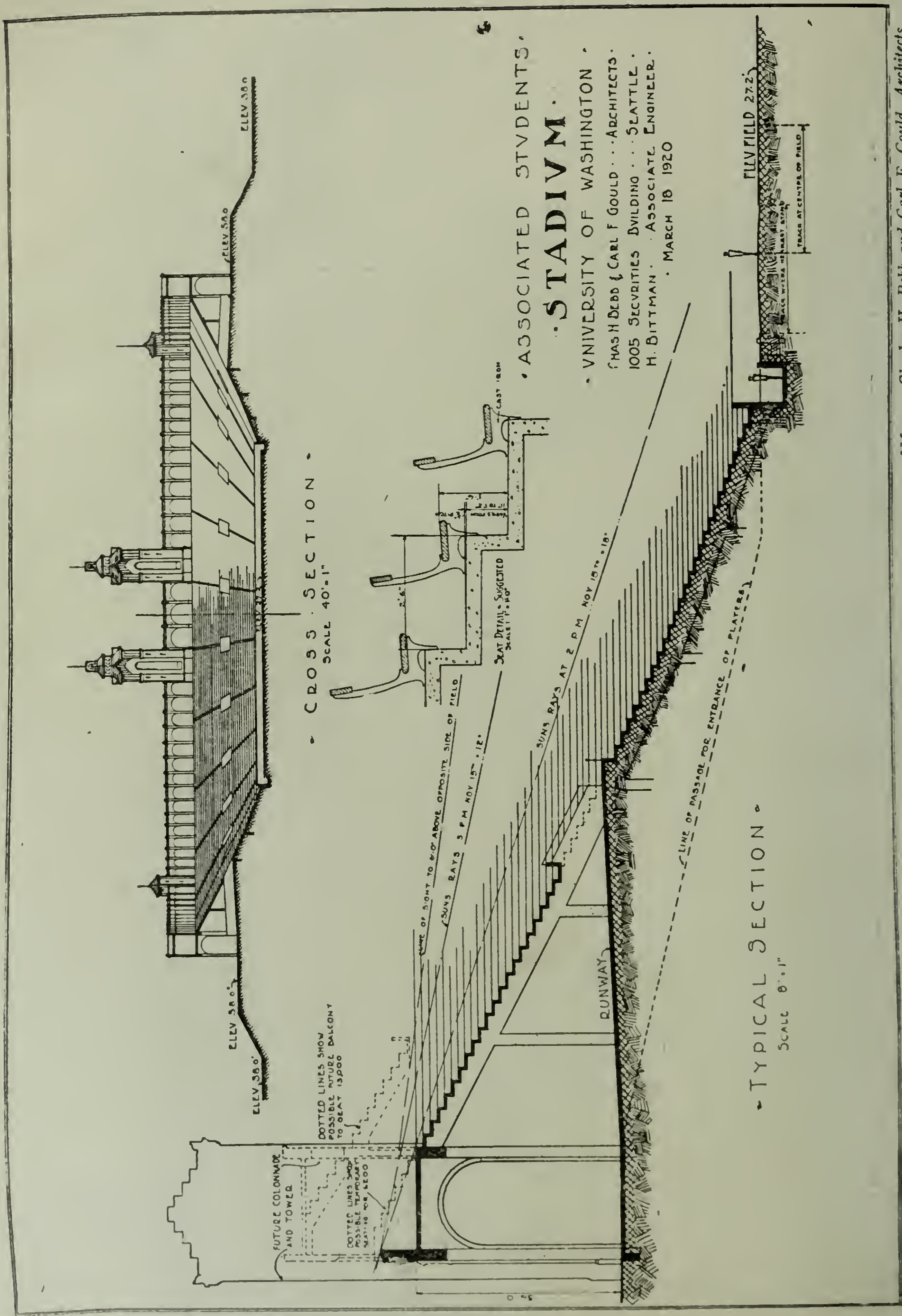
Columns of Loggia in Course of Construction.

The Stadium at the British Empire Exhibition, Wembley.



[Messrs. J. W. Simpson, PP.R.I.B.A., and Maxwell Ayrton, F.R.I.B.A., Architects.

MAIN ENTRANCE TO THE STADIUM: BRITISH EMPIRE EXHIBITION, WEMBLEY. (See p. 699.)



Stadium for the University of Washington. (See p. 705.)

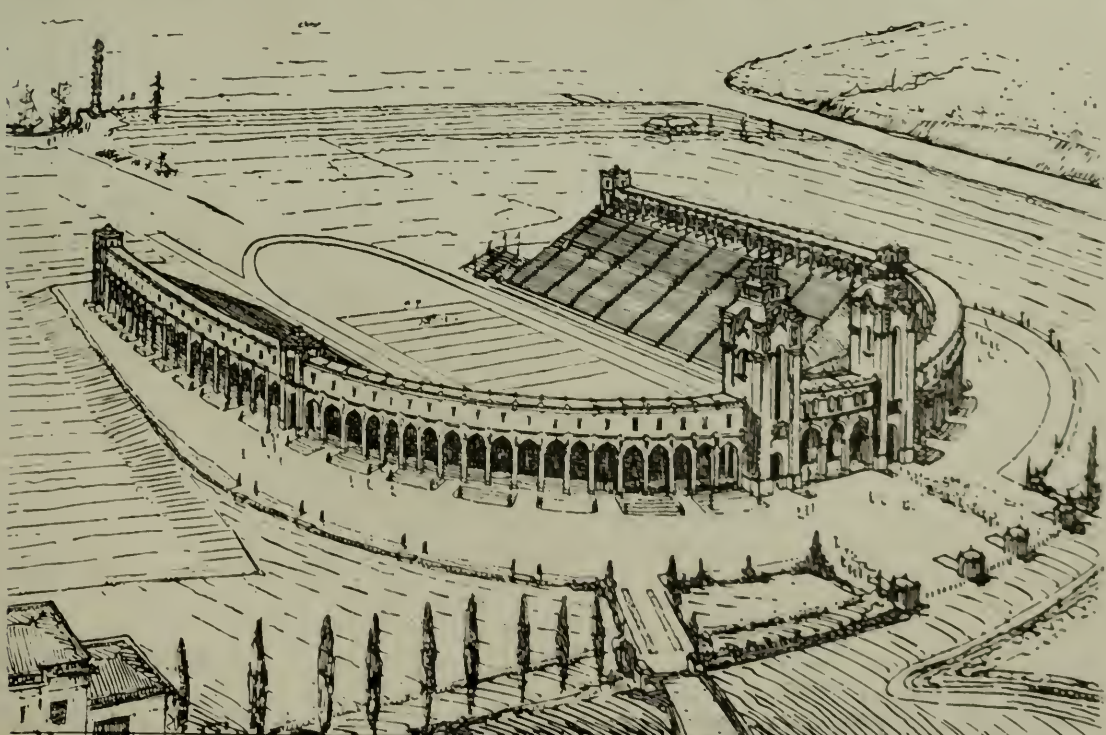
[Messrs. Charles H. Bebb and Carl F. Gould, Architects.

THE WASHINGTON STADIUM.

The construction of the stadium at the University of Washington, Seattle, was decided on early in 1920. Studies for the structure were immediately started, and a committee consisting of a member of the firm of architects and an engineer from the University was sent to examine and report on existing stadia in eastern states. It was determined that the seating capacity of the stadium should be for approximately 60,000, and be constructed in two units. The site rises in gentle slope from zero to 60 ft., and it became apparent that in vertical height one-half of the stadium could be built upon the ground and the second half constructed as a superstructure. Thus, in entering and leaving the structure the people would enter and leave a circulating concourse or platform at the ground level exactly in the centre of the vertical height of the building, and the highest and lowest seats would be equidistant from it. Furthermore, the height of the superstructure above the ground being half the total height of the structure it would lend itself to simple architectural treatment.

The longitudinal axis was tentatively laid out with two points in view: (1) to secure the best vista of lake and mountain from the interior, the open end facing in the easterly direction, and (2) so to locate it in reference to the existing contours of the land that the cut and fill would be equalised as much as possible. It was determined that in addition to the football field there should be a four-lap-to-the-mile running track and a 220-yd. straight track. Horizontal and vertical sight lines were laid out to ensure that any spectator from any seat could view the entire running track without rising or having his view obstructed by the person sitting adjacent to him. The result of these studies eventuated in an elliptical form of plan, which was adopted.

The next point considered was circulation and the best method of filling and emptying the structure in the shortest space of time, and this determined the width and number of aisles. It was decided that the greatest number of persons seated accessible to an aisle should be sixteen at the highest point, and as the aisles radiated the seating accessible to the aisles decreased. This decision proved highly effective, as by actual time carefully recorded the structure was



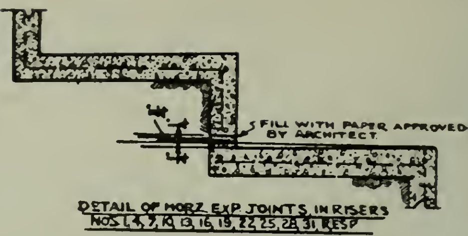
[*Messrs. Charles H. Bebb and Carl F. Gould, Architects.*

STADIUM FOR THE UNIVERSITY OF WASHINGTON.

emptied of 30,000 people in exactly seven minutes.

After the drawings were completed a contract was entered into for the work on May 7, 1920, with the condition that the entire undertaking should be completed by November 27 last year ; this allowed six months and twenty days to complete the structure with all its accessories. The vital problem in relation to time was the matter of the cut and fill, and after considerable study it was decided to adopt the hydraulic method. The contractors immediately began the installation of a pumping unit, consisting of two 10-in. 5-phase turbine pumps directly connected to a 650 h.p. induction motor having a speed of 690 revolutions per minute and a capacity of 4,000 galls. of water per minute against a 370 ft. total head to supply the water to be used in cutting and carrying the soil from the excavation. This installation was completed in twenty days, and on May 27 sluicing operations began. The material to be moved came largely from within the area of the stadium proper, and was to be used and delivered to form the elliptical banks surrounding the field. This necessitated lifting the excavated material together with the transporting water to a height of 42 ft. and forcing it through pipe lines for a maximum distance of 1,400 ft. For this purpose the contractors installed a 12-in. sand pump belt connected to a 200-h.p. slip-ring motor.

The composition of the soil as far as could be determined by sinking test pits and borings consisted of alluvial deposit, sand, gravel, and clay formations, with some indication of hard pan. During the installation of the hydraulic plant the bench forms beginning at the low end at the north-east corner and working west were commenced. These forms were constructed of fir lumber and made collapsible and strongly built so that they could be re-used, the intention being that the benches should be ready for the reinforced concrete work with the least possible cutting, trimming, and filling. On May 27 the pumps were started and streams of water were directed against the material to be excavated, and the soil-laden water was carried in flumes to the sand or booster pump which in turn discharged through a 14-in. steel pipe at the point of fill. Thus excavating and



Detail of Horizontal Expansion Joints in Risers.

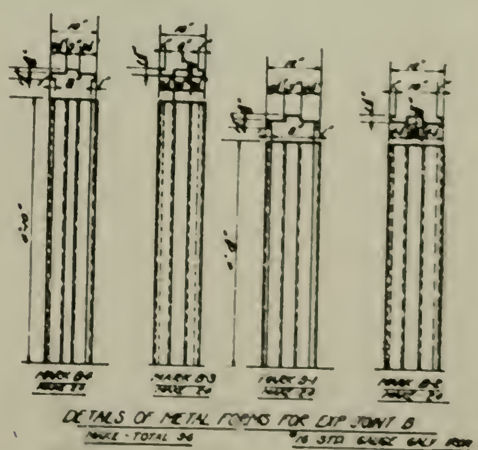
filling proceeded as one process night and day without intermission six days a week. As it was imperative that the fill should take its final settlement quickly, great care was used to reject all clay materials, not only from the benches but from the portions of the fill on which the future superstructure was to rest. This was done by not allowing the water to move slowly enough to deposit any of the clay until it had passed such points. Curves of predicted settlements showing the amount of settlement expected and the time at which settlement would be complete were drawn before starting the work. Curves of actual settlement and the time required were drawn as the work progressed and checked with the prediction curves, and were found to tally with remarkable closeness. Complete settlement of the fills was reached within fifteen days after placing, and a check made one year after placing showed no further settlement, thus demonstrating that the fills were in their final position fifteen days after completion. The concrete forming the seat banks was placed directly on the fill, and in no case does the seat slab or riser exceed the specified thickness by more than one-quarter of an inch and in no place is it less than the specified thickness. It is claimed that by no other method than the hydraulic could a task of such magnitude have been completed in permanent manner in the allotted time. In all, 230,000 cu. yds. of earth were moved, using 687,000,000 galls. of water.

As the allotted time for the settlement in the fill expired the reinforced concrete work followed. To obviate expansion and contraction cracks three different schemes were laid out and full-size models constructed at the site in wood. As a unit of calculating theoretical expansion and contraction horizontally and vertically, a slab of reinforced concrete was taken the equivalent of three risers and benches vertically and the greatest distance between aisles horizontally. The coefficient of extreme variation of temperature was taken at 80 deg. Fahr., and it was found that a movement of three-eighths of an inch might be expected horizontally. The scheme finally adopted was as follows. The aisle steps were laid first and a horizontal mastic expansion joint coinciding with the third riser of the concrete benches was inserted. The steps were allowed to harden thoroughly. Then on each side of the steps a strip of two-ply building paper 4 in. wide was pasted down. This was done to ensure against any possible bond taking place between the slab forming the risers and benches and the aisle steps. The riser and bench slabs were then poured to the extent of three risers and benches at a time. The slab itself was divided in two equal sections with a vertical expansion joint at the centre between aisles and thoroughly anchored to a 14 in. by 8 in. girder following the form of the risers and benches, the pouring of the concrete for girder and slab being done at the same time. A horizontal mastic joint was then laid on the top bench, and the pouring repeated. By taking three sections at a time between aisles work proceeded without interruption. This method has proved highly efficient. Close readings have been taken during the past two years, and the movement observed in extremes of temperature in summer and winter. On the widest slab three-sixteenths of an inch has been the extreme movement, the movement being back and forth over the paper joint on the aisle steps. Sufficient reinforcing only was used to take up the shrinkage in the concrete. At the end of two years no cracks of any kind have appeared. The walls of the sunken passage were built with expansion joints of metal approximately 25 ft. on centre. The benches themselves were constructed with a slight fall back to the riser and crowned in the centre at the expansion joint, with a shallow gutter falling each way to the aisles so that rainwater is carried back to the riser, thence to the aisles on each side, and follows down the steps to the sunken passage. As soon as sufficient set had taken place so that forms could be moved the surface of the risers and benches was finished with carpet float producing a certain amount of texture and reducing the glare from the sun on clear summer days. In all, 3,300 cu. yds. of concrete were poured and 106 tons of reinforcing steel used.

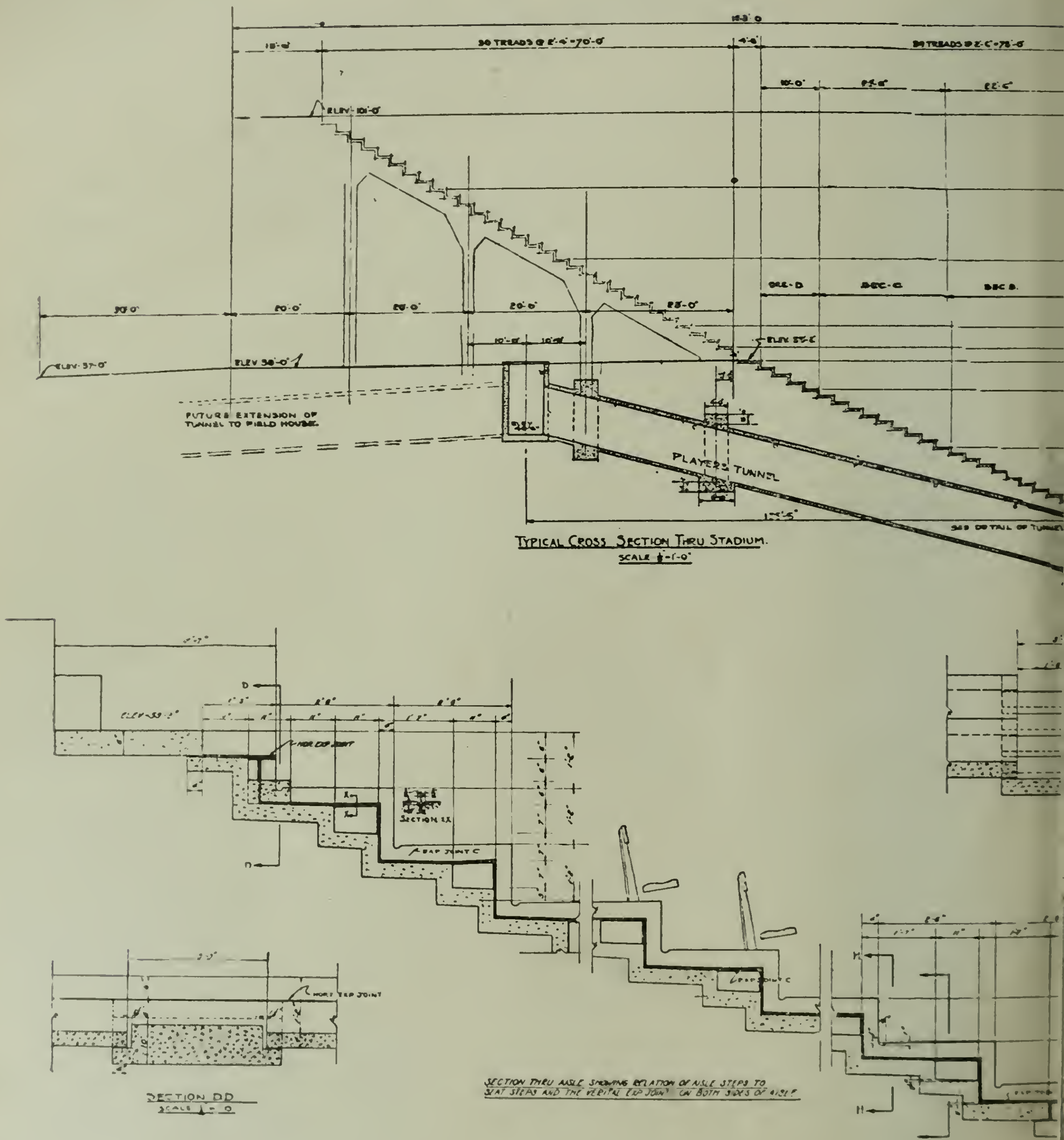
The rainwater falling within the structure proper is gathered to the aisle steps and conducted into the sunken passage, the floor of which is graded to sand-trap storm-sewer catch-basins which in turn are connected to the storm sewer laid below the floor and graded and connected to the outlet sewers leading into the lake. The entire stadium is completely cut off from surface storm water and sub-surface seepage. Back pressure against the risers is therefore impossible, and except when rain is actually falling the seating is permanently dry. Two years' careful observation has demonstrated that all drainage systems are working perfectly.

The contractors' equipment, tools and scaffolding were removed, and notwithstanding practically forty-six days of continual and exceptional rainfall beginning in the middle of October, on November 27 at 2 p.m. the huge structure fully completed was completely filled with spectators ready for the Dartmouth game. The factors which made this undertaking possible in such a remarkably short space of time were, first the youthful enthusiasm and energy of the Committee of the Student Bodies, and secondly co-operation between the architects, engineers, and contractors.

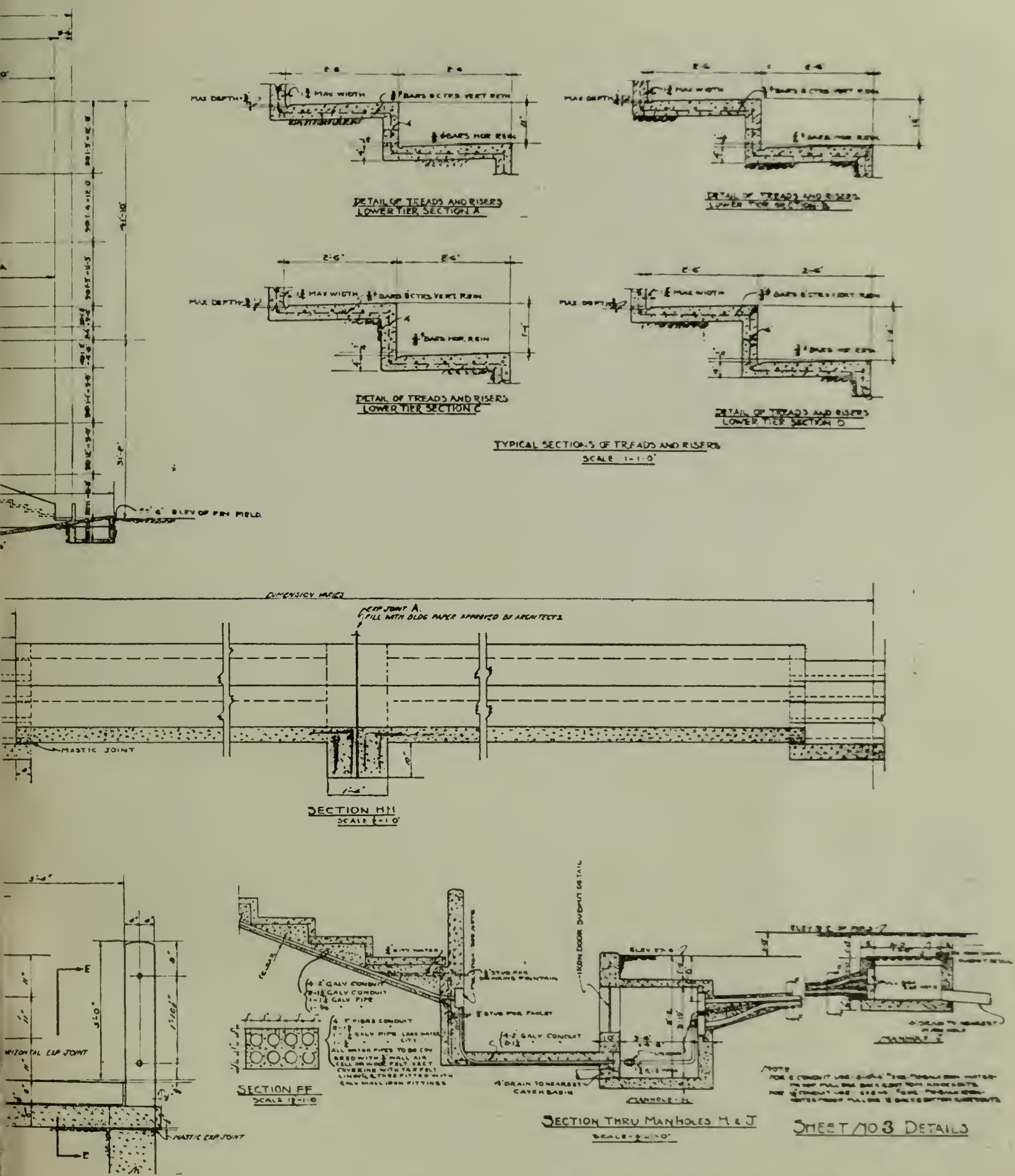
The outside dimensions of the structure are 464 ft. by 570 ft., and the total cost, exclusive of land, 480,000 dollars. The architects are Messrs. Charles H. Bebb, F.A.I.A., and Carl F. Gould, A.I.A., of Seattle, to whom we are indebted for the above particulars and the illustrations.



Metal Forms for Expansion Joint.

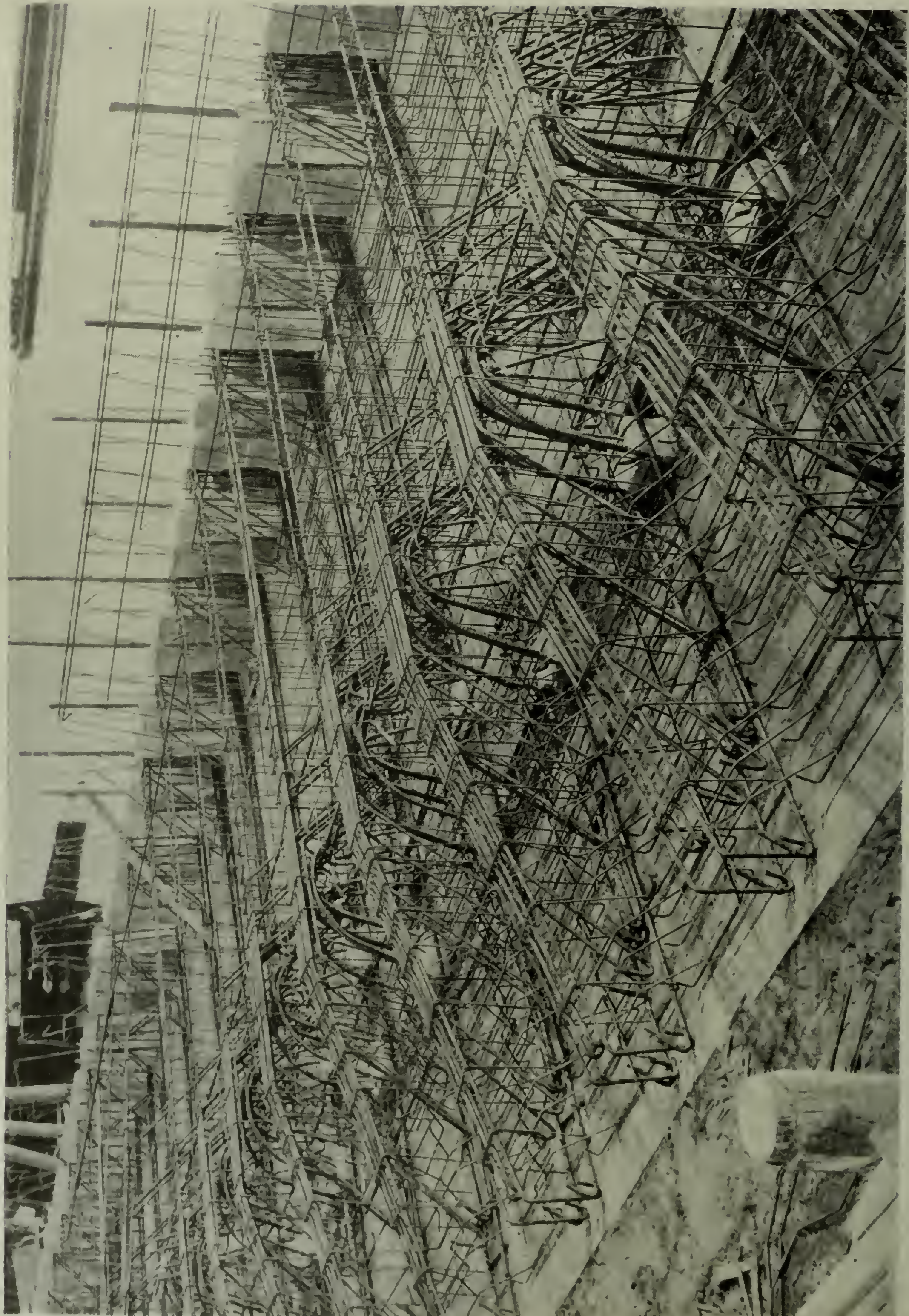


STADIUM FOR THE UNIVERSITY



IGTON, SEATTLE. (See p. 705.)

[Messrs. Charles H. Bebb and Carl F. Gould, Architects.



SUPERSTRUCTURE FOR QUAY WALL, SHOWING REINFORCEMENT OF ANCHOR SLAB AND FRONT WALL. (*See p.* 711.)

SOME SPECIAL TYPES OF RETAINING WALLS.

By R. N. STROYER, B.Sc., M.I.Mech.E.

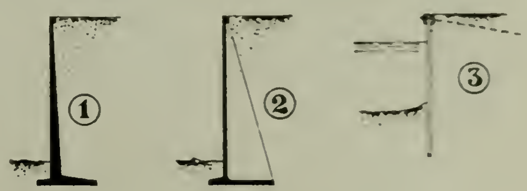
The use of reinforced concrete for retaining walls has resulted in certain standard types being evolved from the gravity wall, and utilising the properties of reinforced concrete as a homogeneous material capable of withstanding both compression and tension. The usual angle design and the ribbed construction are examples of this (*Figs.* 1 and 2), these forms being so well known as to require no further description.

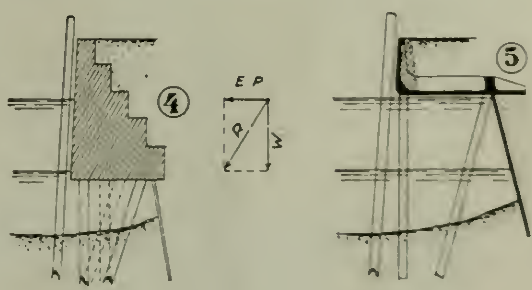
Where circumstances prevent or make difficult the adoption of this form of construction, such as would be the case with sea retaining walls, quay walls, dams, embankments, etc., having their substructure under water, a special type of retaining wall has been employed successfully to a large extent on the Continent, obviating the difficult and costly work behind cofferdams.

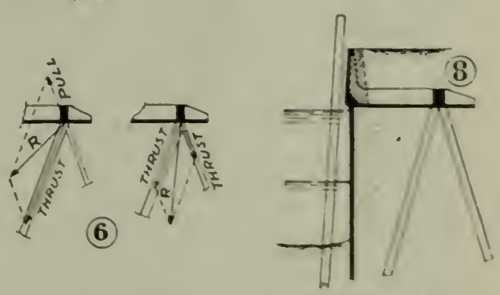
The simplest type of sea retaining wall is that sketched in *Fig.* 3, being a row of sheet piles, or king piles with shutters, anchored back in a suitable manner. This construction was generally executed in timber before the introduction of reinforced concrete, but can be made equally well in the latter material, which has the advantage of being proof against the destructive action of changes in the water level or attacks of the teredo.

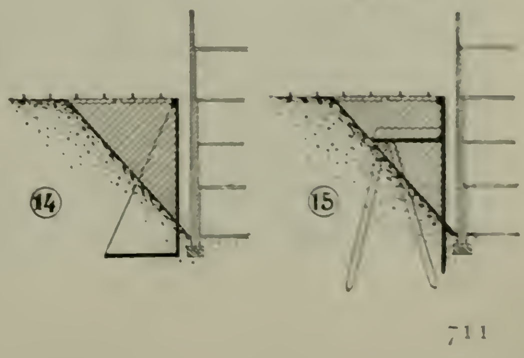
Where a more elaborate wall is required, for instance in the case of a quay wall, a fairly common type of construction is the mass concrete or masonry wall on timber piles, as shown diagrammatically in *Fig.* 4. The retaining sheet piles are generally at the back of the wall, the horizontal thrust from the filling behind being taken by the inclined piles. The number of these should be so determined that the oblique resultant force from the earth pressure and the weight of the superstructure are safely taken by axial stresses in the piles and without imparting bending stresses. To make the timber substructure impervious to the action of the tide it must not extend above low-water level, thus necessitating tide work or cofferdams for the construction of the wall and the timber work on top of the piles.

In *Fig.* 5 is shown the reinforced concrete quay wall evolved from the gravity wall just described. A line of reinforced concrete piles is taking the weight of the front wall and part of the weight of the horizontal slab with the filling over. The remainder of the weight is taken by the back line of inclined piles and the sheet piles. The functions of the horizontally-extended slab are threefold: (1) to impart sufficient weight to the inclined piles to enable them to take the earth pressure from the filling, (2) to transmit the earth pressure from the front wall to the yokes formed by the inclined piles and the sheet piles, and (3) to act as a distributing and strengthening member for resisting blows, shocks, or vibration from vessels moored to the quay.









It will be seen from *Fig.* 6 that by varying the depth of the slab, i.e. the weight on the back piles, the resultant acting on the pile yoke can be altered, so as to give tension or compression (or no stress at all) in the sheet piles, the inclined pile being always stressed to compression. For reasons of economy the horizontal slab, and consequently the weight on the piles, is generally kept as small as possible, resulting in a slight pull on the sheet piles; as these, however, form an excellent tension member on account of the great frictional surface, the resistance against pulling out is very considerable. The sheet piles are joined at the top by means of a strong longitudinal beam running the whole length of the wall, the inclined piles being carried well up into the beam; the front wall can either be a reinforced concrete wall, reinforced as the ordinary angle type, or a mass concrete

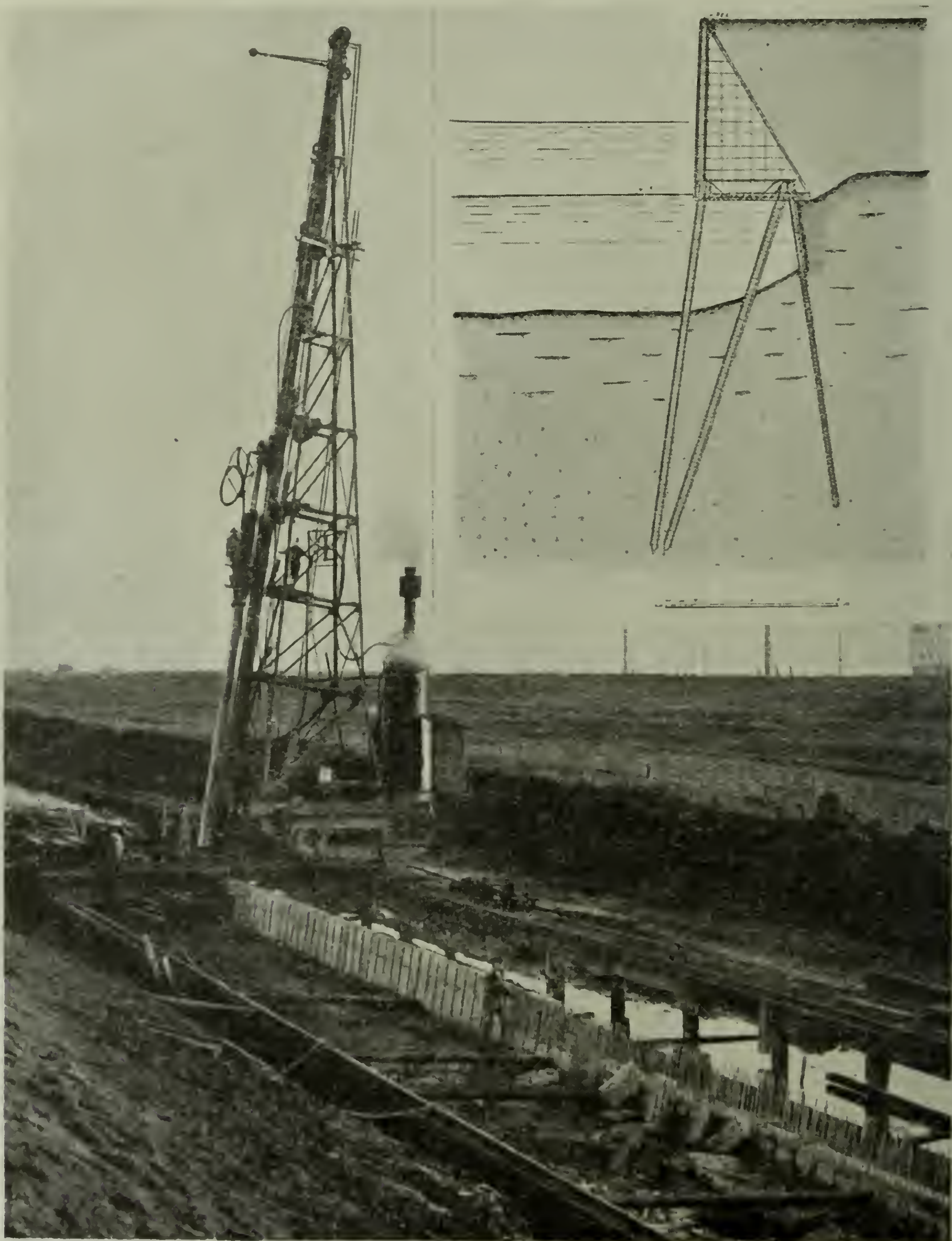


FIG. 7.—QUAY WALL WITH 22 FT. DEPTH OF WATER. TYPICAL CROSS SECTION, SHOWING SHEET WALL BEHIND AND COUNTERFORTED FRONT WALL.

Fig. 9.—Quay Wall, showing Mass Concrete Front Wall with Anchor Slab.

wall may be formed as suggested by the dotted line. As the concrete piles do not suffer harm from changes in the water level, the slab can be laid entirely above high-water level, thus obviating tide work or pumping. An example of this type of wall is shown in *Fig.* 7, a quay wall of 1,300 ft. length and 22 ft. depth of water.

Where a closed front wall is desired the slightly modified construction shown in *Fig.* 8 may be employed. The sheet piles are here placed in front and form a continuous wall from top to bottom. With modern appliances for pile driving it is an easy matter to drive the piles in exact alignment, and an absolute bond between the separate piles can be obtained in several ways. A great advantage offered by this construction lies in the fact that the earth pressure is greatly reduced owing to the presence of the slab. The bending moment acting on the sheet piles is reduced correspondingly, and the necessary anchorage, being a direct function of the earth pressure, is also reduced. Otherwise the action of the slab is the same as in the previous construction, the weight on the pile yokes being so arranged that the back piles have little or no tension. It might be held that the back row of inclined piles could be omitted, since the structure could be so designed that the former had neither tension nor compression. In actual practice the back piles are, however, always driven as an additional safeguard against slight variation in the earth pressure, which it may have been impossible to foresee in the initial calculation. It will be noticed that a surcharge behind the front wall tends to increase, rather than otherwise, the stability of the structure owing to the extra weight over the slab, and in this respect this type of wall differs from most others.

Fig. 13.—Quay Wall at Lowestoft, Reinforcement of Anchor Slab and Front Wall.

Fig. 10.—Substructure for Quay Wall consisting of Front Sheet Piles and Back Yoke Piles.

The advantages of the quay wall just described are shortly :

Stability against earth pressure under all conditions of varying load and water level ; the factor of safety may be made as high as desired.

Resistance to outside forces, shocks, vibration, etc., owing to the great moment of inertia of the angle section.

Immunity against scouring at the root of the foundation.

Homogeneousness of substructure and superstructure.

During the past decade a number of quay walls of this type have been built, in Germany by Messrs. Christiani & Nielsen, Hamburg (*Figs.* 9 to 11), and in this country, to the design of the writer, by Messrs. Somerville (*Figs.* 12 and 13).

FIG. 12.—QUAY WALL AT LOWESTOFT: FRONT SHEET WALL AND YOKE PILES BEING DRIVEN.

An adaptation of this construction for land purposes is shown in *Figs.* 14 and 15, in the shape of a railway retaining wall necessitated by the widening of the line. The work, which had to be executed without interfering with the existing traffic, was greatly facilitated by substituting the pile yoke design for the ordinary angle or gravity wall, which would have necessitated a large amount of dangerous excavation work. The design adopted left the embankment untouched, all the piles being driven into the bank from a temporary staging, and after filling up to the level of the slab, the latter and the top wall were built and filled up. The length of the wall was some 600 ft., and the average height 25 ft.

Concrete Telegraph Posts in France.

WE learn from the *Electrical Review* that, in order to facilitate the transportation and erection of heavy reinforced concrete telegraph posts now being erected throughout its system, the Midi Railway has adopted the following method : A gang proceeds to the site to dig out or blast out a rectangular hole. A special train equipped with concrete mixers and other apparatus for the rapid mixing and pouring of concrete follows when traffic allows, and a rectangular base is cast with a hole cored out, of a rectangular wedge shape to fit the base of the concrete support, with a slight clearance. When these are set, a train is made up of flat cars containing supports, one bogie car being arranged on each side of a high-powered steam crane with a long arm. The steam crane lifts the supports, weighing something like 5 tons each, one by one from the flat car, and they are then tipped up into a vertical position and dropped into the prepared base, where the support is lined up and temporarily fixed by wood wedges to await the filling and grouting-in party. The whole operation, from the flat car to the wedging up, takes in some cases little more than two minutes. In order to turn out these supports cheaply a depôt has been laid out near the railway station at Pau ; concrete mixers, stone breakers, heavy cranes, and special testing gear have been arranged so that they can be cast, seasoned for forty days, and shipped with a minimum of labour.

THE CONCRETE INSTITUTE.

An Extraordinary General Meeting of the Concrete Institute was held in London on October 19, to confirm resolutions passed at an Extraordinary General Meeting held on September 28 with regard to the proposed change of title to "The Institution of Structural Engineers." The President (Mr. E. Fiander Etchells) was in the chair.

After the minutes of the last meeting had been confirmed and signed, Mr. Wentworth-Sheilds moved :—"That this meeting confirms the resolution passed at the last Extraordinary General Meeting, held on September 28th, 1922—'That the name of the Company be changed to The Institution of Structural Engineers.'" In speaking to the resolution, he said he believed they were very nearly all agreed that the proposed change of name was the natural outcome of the work they had been doing in the past, and was due to a desire to express the work they had been doing, and were continuing to do, in a more logical manner than they had hitherto done. Until 1908 there was no special institution dealing with structural engineering, but in that year the Concrete Institute was formed and took up structural work, broadly ; and he believed they would all agree that it had more than justified its existence. The fact that the membership rose to over 1,000 in a very few years, and that the Institute had a printed record of work to show, told very clearly that there was really a very great demand for an institution of that kind. When it was first established it dealt particularly with concrete and reinforced concrete, but very soon it enlarged its borders and admitted those who were interested in allied branches of structural engineering, and he believed that not a single one of them doubted that this broadening of their interests had been of immense advantage to the Institute and to the profession at large. The resolution was the natural and logical outcome of that state of things. They now included within their borders—and were glad to include them—men who had other interests than concrete, who were interested in the many problems that structural engineering involved. They felt they were doing a good work for the profession by including them and allowing them to gain experience and to help one another in the many problems which structural engineering involved. Therefore, they wanted to impress upon themselves, and upon the whole world, what their sphere of usefulness was, and they felt it was sensible and right that they should take a title which would convey that.

Professor Henry Adams, in seconding the resolution, said at the last meeting the resolution was carried by an overwhelming majority, and the meeting that evening was merely a formal one for the purpose of confirming it. It would be a graceful act on the part of the small opposition if they would abstain from voting against the resolution that evening, so that it might be carried *nem. con.*

Mr. Yeatman said he had hoped the Concrete Institute might have continued under its old and most appropriate name, but the majority at the last meeting seemed to think differently, and he did not see a sufficient proportion present that evening to make it worth while opposing the resolution.

The resolution was carried unanimously.

Mr. Jardine proposed a resolution embodying certain alterations to the Articles of Association necessitated by the change, which was seconded by Mr. Barnes and carried *nem. con.*

Mr. Spencer proposed that this meeting confirm the resolution passed at the last Extraordinary General Meeting, held on September 28th, 1922 :—"That the new Articles of Association already approved by this meeting and for the purpose of identification subscribed by the Chairman thereof be, and the same are hereby, approved ; and that such Articles be, and they are hereby, adopted as the Articles of the Company in substitution for and to the exclusion of all the existing Articles thereof."

Mr. Gower Pimm seconded the resolution, which was unanimously passed.

During the proceedings the Chairman mentioned that several members had promised to endeavour to form provincial branches of the Institution.

RECTANGULAR CULVERTS AND TUNNELS.

By A. P. MASON, B.Sc. (Lond).

THE results set forth in this theory of the bending moments which occur in the sides of culverts and tunnels are applicable to structures in which the corners may be considered perfectly rigid and all four sides are of the same thickness or moment of inertia of cross section. This would be the case with tunnels built in reinforced concrete, the sides consisting of continuous slabs spanning between the corners.

CASE I.

First consider the case of a tunnel the height of the vertical sides of which is small compared with its distance below ground level, when the intensity of earth pressure on the vertical sides may be assumed uniform from top to bottom (*Fig.* 1).

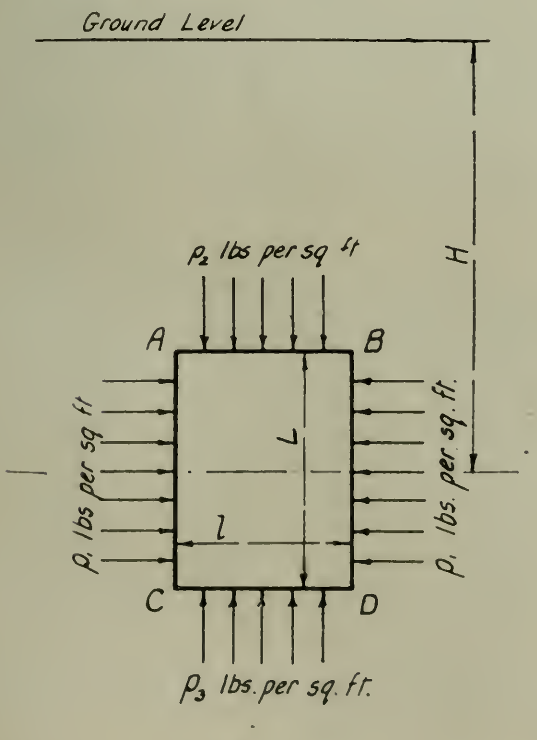


FIG. 1

Let the depth of the centre line of the tunnel below the ground level be H ft. Weight of earth = w lbs. per c. ft.

Angle of repose = φ degrees.

The figure shows a centre line diagram of the sides. The intensity of horizontal, that is normal, pressure on the vertical sides (P_1) will be $wH\dfrac{(1-\sin\varphi)}{(1+\sin\varphi)}$ lbs. per sq. ft., provided that the tunnel is not at so great a depth that pressure is no longer proportional to depth below ground level. In that case the pressure would have to be estimated by other methods. This pressure may be considered uniform from A to C without serious error, provided the ratio of depth of tunnel below ground to height of tunnel is large. If the tunnel were situated under a roadway, or the ground above it were subjected to any superload, a surcharge of an equivalent number of feet of earth would have to be added to H.

The pressure, P_2, on the top of the tunnel will be wH lbs. per sq. ft., and it will be sensibly the same on the bottom, since the weight of the structure would be small compared with that of the earth above it, and in any case it would probably be carried by friction on the earth at the sides. If it is to be included, we must add to P_2 the weight of the tunnel in lbs. per sq. ft. of bearing area. Then P_3 will be the intensity of pressure on the bottom.

In what follows we shall consider a section of the tunnel 1 ft. long.

If the joints A, B, C, and D were free, we should have a bending moment in the centres of the sides A—C and B—D of magnitude $\dfrac{P_1L^2}{8}$. The area (A) of the bending-moment diagram will be

$$\frac{P_1L^2}{8}\times\frac{2}{3}L=\frac{P_1L^3}{12}$$

Similarly, if A_2 and A_3 are the areas of the bending-moment diagrams on the top and bottom respectively:

$$A_2=\frac{P_2l^3}{12}\text{ and }A_3=\frac{P_3l^3}{12}$$

The distances of the centres of gravity of these bending-moment diagrams from the points of support will be equal to half the span in each case.

Applying the theorem of three moments to the bottom and one side (A—C) we obtain the equation :—

$$\frac{A_3}{2}+\frac{A_1}{2}=\frac{M_Dl}{6}+\frac{M_C(L+l)}{3}+\frac{M_AL}{6}$$

Similarly, considering the side A—C and the top :—

$$\frac{A_1}{2}+\frac{A_2}{2}=\frac{M_C L}{6}+\frac{M_A(L+l)}{3}+\frac{M_B l}{6}$$

Due to symmetry, the fixing moments at A and B will be equal, and also at C and D. The two equations may then be written as follow :—

$$\frac{A_3}{2}+\frac{A_1}{2}=\frac{M_C l}{6}+\frac{M_C(L+l)}{3}+\frac{M_A L}{6}$$

$$\frac{A_1}{2}+\frac{A_2}{2}=\frac{M_C L}{6}+\frac{M_A(L+l)}{3}+\frac{M_A l}{6}$$

This is a pair of simultaneous equations from which the values of M_A and M_C may be obtained. Putting in the values of A_1, A_2, and A_3, these are :—

$$M_A=\frac{l^2L(P_2-P_3)+3P_2l^3+3P_1L^3}{36l+24L}$$

$$M_C=\frac{l^2L(P_3-P_2)+3P_3l^3+3P_1L^3}{36l+24L}$$

If $L=xl$,

$$M_A=\frac{l^2x(P_2-P_3)+3l^2(P_2-x^3P_1)}{36+24x}$$

$$M=\frac{l^2x(P_3-P_2)+3l^2(P_3-x^3P_1)}{36+24x}$$

If the intensities of pressure on the top and bottom are assumed to be equal, then the fixing moments at all four corners will be equal, and of magnitude

$$\frac{P_2l^3+P_1L^3}{12l+8L}, \text{ or if } L=xl, \ \frac{l^2(P_2-x^3P_1)}{12+8x}.$$

Having obtained these fixing moments it is a simple matter to plot the complete bending-moment diagrams (*Fig.* 2). The

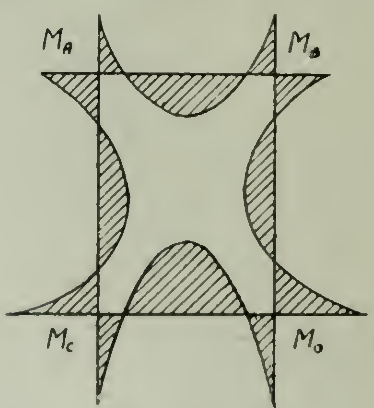


FIG 2

maximum value of positive bending moment on the top will be $\frac{P_2l^2}{8}-M_A$ and for the bottom $\frac{P_3l^2}{8}-M_C$.

If it is required to find the exact maximum positive bending moment on the sides and the point where it occurs, this is obtained as follows :—

The bending moment M at any point distant y ft. from C is equal to :

$$\frac{P_2yL}{6}+\frac{P_3yL}{3}-\frac{P_3y^2}{2}+\frac{P_3y^3}{6L}-\frac{P_2y^3}{6L}$$
$$-M_A-(M_C-M_A)\frac{y}{L}$$

For the position of maximum bending moment $\frac{dM}{dy}=0$, that is,

$$\frac{L}{6}(P_2+2P_3)-P_3y+\frac{y^2}{2L}(P_3-P_2)-\frac{M_C-M_A}{L}=0.$$

From this quadratic equation the value of y may be found in any particular example by putting in the numerical values of the other quantities. Substituting this value of y in the expression for M gives the maximum positive bending moment in the sides. This may come out to a small negative value if the pressures on the top and bottom are much greater than on the sides, or if the height of the tunnel is not much greater than the width.

CASE II.

Tunnel at a comparatively shallow depth below ground level.

Fig. 3 is a centre line diagram of the four sides, showing the distribution of pressure. If the top is at a distance H ft. below the level of the ground, the pressure P_1 on the top will be wH lbs. per sq. ft., allowance being made for superload if necessary. On the bottom the pressure P_4 will be greater than P_1 by an amount equal to the weight of the tunnel in lbs. per sq. ft. of bearing area.

It is first necessary to find the areas and the positions of the centres of gravity of the free bending moment diagrams for the four sides.

Vertical sides.—The intensity of pressure Py at a point distant y ft. from D

$$=P_3-(P_3-P_2)\frac{y}{L}=P_3\left(1-\frac{y}{L}\right)+P_2\frac{y}{L}.$$

Considering A—D as a simply-supported slab, the reaction R_D at D due to the horizontal pressure is

$$\frac{P_2L}{2}+\frac{2}{3}(P_3-P_2)\frac{L}{2}=\frac{L}{6}(P_2+2P_3).$$

The free bending moment, My, at any section distant y ft. from D, is :—

$$\frac{yL}{6}(P_2+2P_3)-\left[P_3\left(1-\frac{y}{L}\right)+\frac{P_2 y}{L}\right]\frac{y^2}{2}-(P_3-P_2)\frac{y^3}{3L}=\frac{P_2 yL}{6}+\frac{P_3 yL}{3}-\frac{P_3 y^2}{2}+\frac{P_3 y^3}{6L}-\frac{P_2 y^3}{6L}$$

The area, A_2, of the free bending moment diagram $=\int_{y=L}^{y=0} M dy$

$$=\left[\frac{P_2 L y^2}{12}+\frac{P_3 L y^2}{6}-\frac{P_3 y^3}{6}+\frac{P_3 y^4}{24L}-\frac{P_2 y^4}{24L}\right]_L^0=\frac{L^3}{24}(P_2+P_3)$$

Let $\bar{y}_2$ = the distance of the centre of gravity from the end D.

Then $$\bar{y}_2=\frac{\int_L^0 My\,dy}{\int_L^0 M\,dy}=\frac{\int_L^0 My\,dy}{A_2}$$

Whence $$A_2\bar{y}_2=\int_L^0 My\,dy$$

Evaluating this integral,

$$A_2\bar{y}_2=\frac{L^4}{360}(8P_2+7P_3)$$

For the top the area of the free bending moment diagram is $A_1=\frac{P_1 l^3}{12}$ and its centre of gravity is at halfspan, i.e. $\bar{y}_1=\frac{l}{2}$. For the bottom the corresponding values are :—

$$A_4=\frac{P_4 l^3}{12}\text{ and }\bar{y}_4=\frac{l}{2}$$

Applying the theorem of three moments, two equations can be formed from which the fixing moments at the corners may be found.

Considering the vertical side and top, (1) $\frac{A_2\bar{y}_2}{L}+\frac{A_1\bar{y}_1}{l}=\frac{M_D L}{6}+\frac{M_A(L+l)}{3}+\frac{M_B l}{6}$.

Considering the bottom and a vertical side, (2) $\frac{A_4\bar{y}_4}{l}+\frac{A_2(L-\bar{y}_2)}{L}=\frac{M_C l}{6}+\frac{M_D(L+l)}{3}+\frac{M_A L}{6}$.

M_A and M_B will obviously be equal and also M_C and M_D. $\frac{\bar{y}_1}{l}$ and $\frac{\bar{y}_4}{l}$ are equal to $\frac{1}{2}$.

Rewriting the equations, (1) $\frac{A_2\bar{y}_2}{L}+\frac{A_1}{2}=\frac{M_D L}{6}+\frac{M_A(L+l)}{3}+\frac{M_A l}{6}$

(2) $\frac{A_4}{2}+\frac{A_2(L-\bar{y}_2)}{L}=\frac{M_D l}{6}+\frac{M_D(L+l)}{3}+\frac{M_A L}{6}$.

Solving these equations for M_A and M_D,

$$M_A=\frac{\frac{A_2\bar{y}_2}{2}\left(1+\frac{l}{L}\right)-\frac{L}{6}\left(A_2+\frac{A_4}{2}\right)+\frac{A_1}{2}\left(\frac{L}{3}+\frac{l}{2}\right)}{\frac{L^2}{12}+\frac{Ll}{3}+\frac{l^2}{4}}$$

$$M_D = \frac{\left(\frac{A_4}{2} + A_2\right)\left(\frac{L}{3} + \frac{l}{2}\right) - \frac{A_2\bar{y}_2}{2}\left(1 + \frac{l}{L}\right) - \frac{A_1 L}{12}}{\frac{L^2}{12} + \frac{Ll}{3} + \frac{l^2}{4}}$$

Substituting the value $L = xl$, the equations become :—

$$M_A = \frac{\frac{A_2\bar{y}_2}{2}\left(1 + \frac{1}{x}\right) - \frac{xl}{6}\left(A_2 + \frac{A_4}{2}\right) + \frac{A_1 l}{2}\left(\frac{x}{3} + \frac{1}{2}\right)}{l^2\left(\frac{x^2}{12} + \frac{x}{3} + \frac{1}{4}\right)}$$

$$M_D = \frac{l\left(\frac{A_4}{2} + A_2\right)\left(\frac{x}{3} + \frac{1}{2}\right) - \frac{A_2\bar{y}_2}{2}\left(1 + \frac{1}{x}\right) - \frac{A_1 xl}{12}}{l^2\left(\frac{x^2}{12} + \frac{x}{3} + \frac{1}{4}\right)}$$

In working out any particular example the values of A_2, $A_2\bar{y}_2$, A_1, and A_4 should be calculated and substituted in these equations ; putting in the values of l and x, the results may be easily obtained.

The complete bending-moment diagram for the four sides can now be plotted and the maximum values of positive moment (if any) scaled from the diagram.

Example.—Tunnel 10 ft. by 8 ft. internal dimensions. Thickness of walls 9 in. Dimensions on centre lines of walls are shown in *Fig.* 4. The depth below the ground is 6 ft. Weight of earth, $w = 100$ lbs. per cu. ft. Angle of repose, $\varphi = 30$ degrees. $w\left(\frac{1 - \sin\varphi}{1 + \sin\varphi}\right) = 100 \times \frac{1}{3} = 33{\cdot}33$ = equivalent fluid weight. $P_1 = 6 \times 100 = 600$ lbs. per sq. ft.

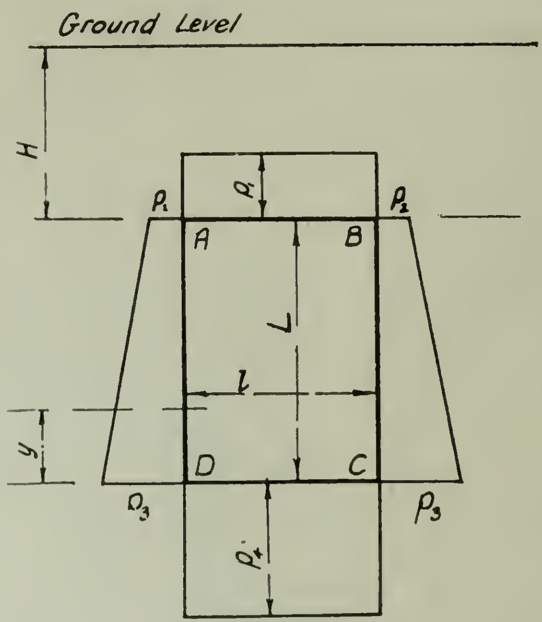


FIG. 3

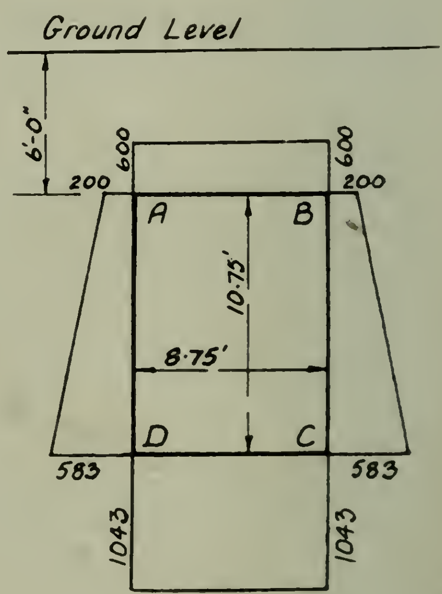


FIG. 4

Weight of tunnel per sq. ft. of bearing surface $= \frac{19{\cdot}5 \times 2 \times 108}{9{\cdot}5} = 443$ lbs. per sq. ft.

$P_4 = 600 + 443 = 1{,}043$ lbs. per sq. ft.

$P_2 = 33{\cdot}33 \times 6 = 200$ lbs. per sq. ft.

$P_3 = 33{\cdot}33 \times 17{\cdot}5 = 583$ lbs. per sq. ft.

$A_2 = \frac{10{\cdot}75^3}{24} \times (200 + 583) = 40{,}500.$

$$A_2\bar{y}_2 = \frac{10{\cdot}75^4}{360}(8\times 200+7\times 583)=173{,}500.$$

$$A_1 = \frac{600\times 8{\cdot}75^3}{12}=33{,}500$$

$$A_4 = \frac{1{,}043\times 8{\cdot}75^3}{12}=58{,}100.$$

$$x = \frac{10{\cdot}75}{8{\cdot}75}=1{\cdot}229.$$

$$M_A = \frac{\frac{173{,}500}{2}\times\left(1+\frac{1}{1{\cdot}229}\right)-\frac{10{\cdot}75}{6}\left(40{,}500+\frac{58{,}100}{2}\right)+\frac{33{,}500\times 8{\cdot}75}{2}\times\left(\frac{1{\cdot}229}{3}+\frac{1}{2}\right)}{8{\cdot}75^2\times\left(\frac{1{\cdot}229^2}{12}+\frac{1{\cdot}229}{3}+\frac{1}{4}\right)}$$

$$=3{,}060 \text{ lbs. ft.} =36{,}700 \text{ lbs. ins.}$$

$$M_D = \frac{8{\cdot}75\times\left(40{,}500+\frac{58{,}100}{2}\right)\left(\frac{1{\cdot}229}{3}+\frac{1}{2}\right)-\frac{173{,}500}{2}\times\left(1+\frac{1}{1{\cdot}229}\right)-\frac{33{,}500\times 10{\cdot}75}{12}}{8{\cdot}75^2\times\left(\frac{1{\cdot}229^2}{12}+\frac{1{\cdot}229}{3}+\frac{1}{4}\right)}$$

$$= 5{,}800 \text{ lbs. ft.} =69{,}600 \text{ lbs. ins.}$$

To find the position and maximum value of positive bending moment on the sides, we have that the bending moment M at any point distant y from D

$$=\frac{y.L}{3}\left(\frac{P_2}{2}+P_3\right)-\frac{P_3y^2}{2}+\frac{y^3}{6L}(P_3-P_2)-M_D+(M_D-M_A)\frac{y}{L}.$$

For a maximum value $\frac{dM}{dy}=0.$

$$\therefore\left(\frac{P_2}{2}+P_3\right)\frac{L}{3}-P_3y+\frac{y^2}{2L}(P_3-P_2)+\frac{M_D-M_A}{L}=0.$$

Substituting our figures in this equation,

$$\frac{10{\cdot}75}{3}\times\left(\frac{200}{2}+583\right)-583y+\frac{y^2}{2\times 10{\cdot}75}\times(583-200)+\frac{5{,}800-3{,}060}{10{\cdot}75}=0.$$

Solving this quadratic, $y=5{\cdot}57$ ft. Then inserting the value of y in the expression for the bending moment gives the maximum bending moment,

$$M \max = \frac{5{\cdot}57\times 10{\cdot}75\times 683}{3}-\frac{583\times 5{\cdot}57^2}{2}+\frac{5{\cdot}57^3\times 383}{6\times 10{\cdot}75}-5{,}800+\frac{(5{,}800-3{,}060)\times 5{\cdot}57}{10{\cdot}75}$$

$$=1{,}205 \text{ lbs. ft.} =14{,}460 \text{ lbs. ins.}$$

The maximum positive bending moment on the top is $600\times 8{\cdot}75^2\times 1{\cdot}5-36{,}700.$
$=32{,}200$ lbs. ins.

and on the bottom

$$=1{,}043\times 8{\cdot}75^2\times 1{\cdot}5-69{,}600.$$
$$=50{,}100 \text{ lbs. ins.}$$

From this data the complete bending-moment diagram can be plotted (*Fig.* 5).

In designing a tunnel it is also advisable to consider the effect of the side pressure on the walls not being realised. This would decrease the fixing moments at the corners, but increase the central positive bending moments considerably. The vertical sides would get negative moment throughout.

The values of the fixing moments may be worked out by the formulae in Case I, putting $P_1=0$, $P_2=600$ lbs. per sq. ft., and $P_3=1{,}043$ lbs. per sq ft.

$$M_A = -\frac{8{\cdot}75^2\times 1{\cdot}229\times(600-1{,}043)+3\times 8{\cdot}75^2\times 600}{36+24\times 1{\cdot}229}$$

$$=1{,}468 \text{ lbs. ft.} =17{,}600 \text{ lbs. ins.}$$

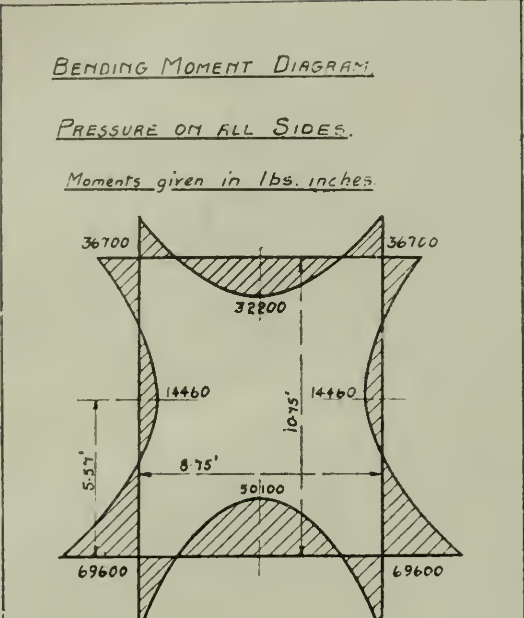


Fig. 5

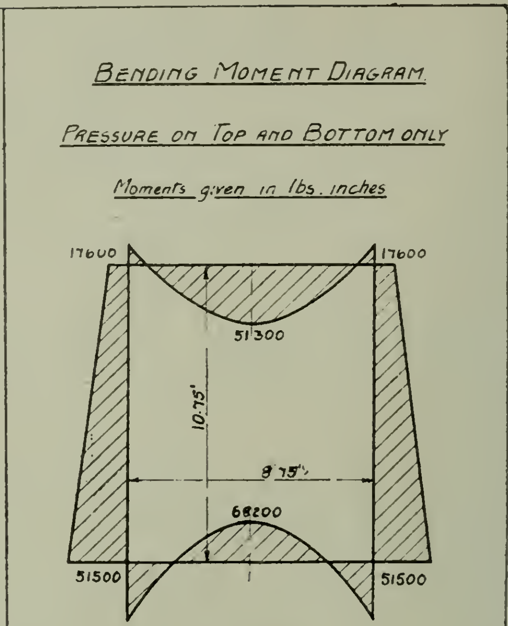


Fig. 6

$$M_D = \frac{8{\cdot}75^2 \times 1{\cdot}229 \times (1{,}043 - 600) + 3 \times 8{\cdot}75^2 \times 1{,}043}{36 + 24 \times 1{\cdot}229}$$

$= 4{,}290$ lbs. ft. $= 51{,}500$ lbs. ins.

The maximum positive bending moment on the top is $600 \times 8{\cdot}75^2 \times 1{\cdot}5 - 17{,}600 = 51{,}300$ lbs. ins.

and on the bottom

$= 1{,}043 \times 8{\cdot}75^2 \times 1{\cdot}5 - 51{,}500$

$= 68{,}200$ lbs. ins.

A second bending-moment diagram may be plotted from this data (*Fig.* 6).

Large New London Swimming Bath.

A new open-air swimming bath recently opened at Bellingham, S.E., and built last winter from the design of Mr. W. F. Owsley, Borough Engineer of Lewisham, has a water surface of 150 ft. by 60 ft., the walls varying in height from 3 ft. to 7 ft. 6 in., the total water capacity being 275,000 galls. The river Ravensbourne was diverted for the purpose of forming the bath, which is of reinforced concrete, and particular attention had to be given to the floor, which was constructed after the form of a raft. The floor, which has a thickness of 12 in., was reinforced with steel wire lattice, and has maintained absolute water-tightness since the opening of the baths. The aggregate for the walls and floors was Thames ballast and cement (6 to 1), the finishing coat being ½ in. of 2 to 1 and ¼ in. of 1 and 1 sand and cement. The steps are inset in the decking, and do not project into the pool. The dressing-boxes are built almost entirely in concrete, with clinker from the Council's adjacent destructor. The reinforcement was supplied by Messrs. Johnson's Reinforced Concrete Engineering Co., Ltd.

REINFORCED CONCRETE AND FIRE-RESISTANCE.

III. ACTION OF SILICA UNDER HEAT TREATMENT.

By J. SINGLETON-GREEN, B.Sc., A.M.C.I., M.Am.C.I.

QUARTZ, TRIDYMITE AND CRISTOBALITE.

ALL these minerals are forms of silicon dioxide (SiO_2), the first two being commonly found in rocks of the earth's crust. Cristobalite, however, has been found in nature only rarely, and then usually together with tridymite.

Recent work on the silica problem has shown it to be much more complicated than was at first supposed. Several distinct phases occur,[1] α-quartz being the ordinary quartz of mineralogists.

α-quartz changes to β-quartz at 575° C.
α-tridymite changes to β_1-tridymite at 117° C.
β_1-tridymite changes to β_2-tridymite at 163° C.
α-cristobalite changes to β-cristobalite at 220°–275° C.
Quartz changes to tridymite at 870° C.
Tridymite changes to cristobalite at 1,470° C.

So we have quartz as the stable phase of silica below about 870° C.; α-quartz being stable below about 575° C., and β-quartz stable above 575° C. Quartz is consequently the unstable form of silica above about 870° C., and will go over into tridymite whenever conditions favourable to the change are present.

CHALCEDONY, OPAL, FLINT, CHERT AND HORNSTONE.

Chalcedony is still another form of silica, and is the chief constituent of flint, which is well known as nodules occurring in the chalk and as pebbles derived from them in the widespread gravel deposits of the home counties and the south-east coast (England).

Opal is another form of silicon with variable amounts of water, the composition being $SiO_2 + n.H_2O$. The proportion of water which it contains varies considerably: the ordinary amount is from 5 per cent. to 10 per cent.; some varieties contain as much as 30 per cent.; some are practically anhydrous. Quartz is present in some instances, in other cases tridymite is present.

Flint, chert, and hornstone are common types of chalcedony, and cannot easily be discriminated. Flint has a conchoidal fracture, but hornstone and chert have a more or less flat fracture.

Since chalcedony is known not to be a cryptocrystalline variety of quartz, the available data relating to the heat treatment of quartz cannot be applied to chalcedony.

EXPANSION OF QUARTZ.

In his report on the Far Rockaway Fire (New York, November 10, 1916), Mr. Ira H. Woolson states[2] that concrete in which quartz gravel is used must be condemned as a first-class fire-resisting mixture, one cause of failure probably being due to the relatively large coefficient of expansion of the quartz.

Quartz: cub. coeff. = ·000036[3]
Felspar: cub. coeff. = ·000017.

Again, the expansion of quartz in the direction of the major axis is only half that in the direction of the axis perpendicular to the major axis. This unequal expansion may further contribute to its tendency to disintegrate the concrete under the action of heat.

Hintze gives the following figures:—

At 40° C.—along main axis—coeff. of exp. of quartz = ·00000781.
perpendicular to main axis coeff. of exp. of quartz = ·0000142.

That is, the coefficient of expansion along the main axis is only 0·55 times that in a direction perpendicular to the main axis. Using the above figures of Hintze we can say that approximately the cubical coefficient of expansion of quartz is 2 (·0000142) + (·00000781) = ·0000362. This figure agrees with that quoted in Clark's *Constants of Nature.*

The following table (to be read in conjunction with the graph) worked from figures by Day, Sosman, and Hostetter,[4] shows the percentage increase in the volume of quartz with increase of temperature.

[1] C. N. Fenner in *American Journal of Science*, 4th Series, Vol. 36, No. 214, Oct. 1913.

[2] B.F.P.C. Red Book, No. 214.

[3] Clark's *Constants of Nature*, Smithsonian Institute, U.S.A.

[4] *American Journal of Science*, 4th Series, Vol. 37, No. 217, January, 1914.

Temperature in degrees C.	Percentage increase of volume.	Remarks.
20	0·0	
450	2·4	
550	3·7	
585	5·2	
600	5·2	
700	4·9	
800	4·7	
900	4·7	
950	—	Gas evolution beginning.
Gas escap	ing rapidly.	
1,250	4·8	Gas evolution ceased.
1,300	5·0	
1,400	6·5	
1,500	10·0	
1,600	19·7	

The figure illustrates clearly the various volume changes in quartz due to heating. The volume increases more and more rapidly as the inversion temperature (575° C.) is approached. Beyond that temperature the volume seems to decrease slightly. The escape of gases beyond 950° C. interrupts the measurements, but above 1,250° C., when the evolution of gas had practically ceased, there are a few points which indicate that the volume either continues constant or goes on diminishing over the range from 950° C. to 1,250° C. About this time, however, the formation of cristobalite becomes rapid and the volume begins to increase greatly.

No effect due to the rate of heating was noticed, and the volumes obtained on lowering the temperature were practically the same as with rising temperature, except for a small increase (about 0·2 per cent.) due to the formation of a few cracks at the inversion temperature.

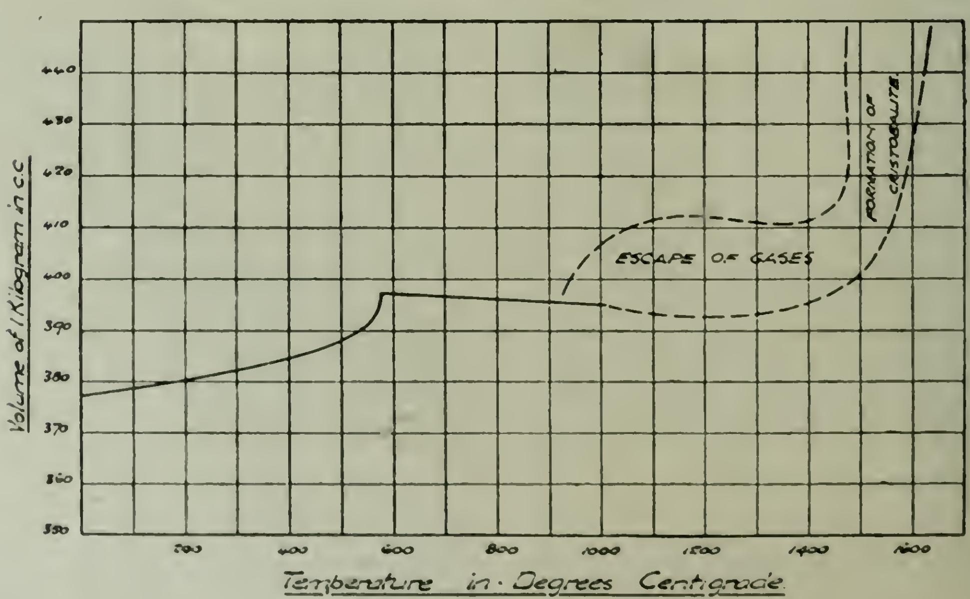
Fenner [1] has shown that quartz is the stable form of silica under atmospheric pressure only up to 870° C. From 870° C. to 1,470° C. tridymite is stable, and above 1,470° C. cristobalite is stable. Quartz in the dry state will not pass directly into tridymite between 870° C. and 1,470° C., but above 1,000° C. it will be converted directly, though slowly, into cristobalite. At 1,300° C. this conversion is fairly rapid.

In every case the cristobalite formed first on the exposed surfaces, and grew inward. This dependence of the growth of cristobalite upon the surface exposed has been noted before.[2] In one instance the apparent volume increase amounted to 52 per cent. On account of the friable and porous character of the cristobalite formed, however, this is considerably larger than the true increase. At 20° C. the true specific volume of cristobalite is 13·4 per cent. greater than that of quartz.

[1] *American Journal of Science*, 4th Series, Vol. 36, No. 214, Oct. 1913.
[2] Endell and Rieke, *Zs. anorg. Chem.*, Vol. 79, pp. 239–259, 1912.

EXPANSION OF QUARTZ.

(After Day, Sosman and Hostetter)



The volume change in quartz between 0° C. and 500° C. is 2·8 per cent., and between 500° C. and 575° C. it is 2·4 per cent. of the volume at 0° C. In other words, the increase during the last 75° C. before the transition point from low to high temperature quartz is nearly as great as the increase during the preceding 500° C.

EXPANSION OF FLINT.

Experiments carried out by Mellor and Campbell[1] indicate that flint actually does expand more rapidly and to a greater extent than quartz. Specimens of the two minerals were subjected to successive firings and the specific gravities were determined after each firing. The specific gravities, however, were measured at ordinary temperatures, so that they indicate the permanent expansion and not that achieved at the temperature of the firings. Dr. Holmes recalculated the results in terms of volume instead of specific gravity, and the following figures have been worked out to give percentage increases in volume.

PERMANENT EXPANSION OF FLINT AND QUARTZ.

No. of firings.	Vol. of 1 kilogram in c.c.		Percentage Increase.	
	Flint.	Quartz.	Flint.	Quartz.
0	383	376	0·0	0·0
1	427	388	11·5	3·2
2	441	400	15·1	6·4
3	448	408	17·0	8·5
4	448	413	17·0	9·8
5	448	418	17·0	11·2
6	448	420	17·0	11·7
7	448	423	17·0	12·5
8	450	426	17·5	13·3

It is evident, then, from these figures that after a single firing flint expands permanently about as much as quartz does after six firings. Tests carried out by the British Fire Prevention Committee confirm these results. Measurements of the deflections of plain concrete slabs indicated that where flint was the coarse aggregate the deflections were roughly twice as much as those where quartz was the coarse aggregate, and we may say the amount of deflection of a plain concrete slab may be taken as approximately proportional to the expansion of the coarse aggregate.

[1] *Transactions*, English Ceramic Society, Vol. 15, p. 80, 1915–16.

CONCLUSIONS.

There seems to be no doubt that aggregates containing high percentages of silica cannot be considered as first class fire-resisting materials. The abrupt change of volume of quartz at 575° C. tends to cause spalling of the concrete, thereby exposing the reinforcement. Spalling can be prevented in some measure by the use of wire ties to hold in the concrete, but even if this is successful, there is another danger at higher temperatures. At 950° C. gas is evolved, and from 1,250° C. upwards the volume increases rapidly owing to the formation of cristobalite. These temperatures are easily reached in fires, so that here again quartz is a failure. Even at low temperatures the unequal expansion of quartz in different directions makes the material unreliable.

As for flint, this seems to be even worse than quartz. Experimental evidence[2] and practical results concur in proving beyond doubt that flint as an aggregate or a constituent of an aggregate is capable of even less fire resistance than quartz. Unfortunately, most British gravels contain flint, quartz, or quartz-bearing rocks as their chief ingredients, and their abundance and wide distribution have led to their having been widely adopted as aggregates. It is, therefore, a matter of serious economic importance to ascertain whether it would not be possible to continue to use flint or quartz-bearing gravels for concrete by protecting the latter with fire-resistant coverings.

This detailed consideration of the action of quartz under heat will enable the action of various aggregates exposed to fire to be understood the more clearly, and will help in the classification of aggregates from the point of view of fire-resistance.

[2] B.F.P.C. Red Book, No. 256, p. 159.

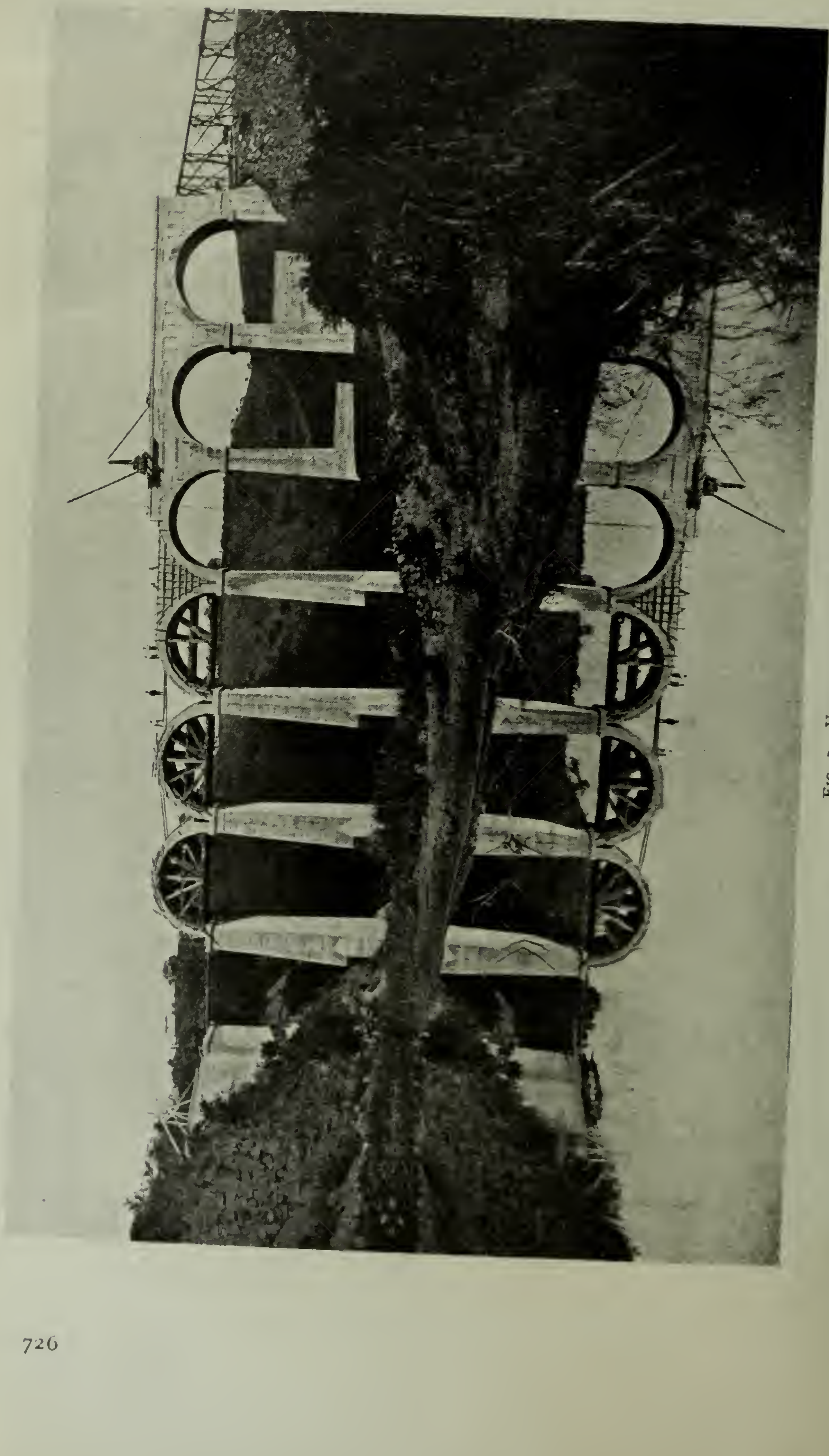


Fig. 1.—Umhlatuzan River Viaduct.
Concrete Work on the Cato Ridge-Clairwood Deviation. (See p. 727.)

CONCRETE WORK ON THE CATO RIDGE–CLAIRWOOD DEVIATION.

THIS line is a deviation of a portion of the main line of the South African Railways between Durban and Pietermaritzburg. It leaves the old main line at South Coast Junction, 4½ miles from Durban, and joins it again at Cato Ridge station, which is 45 miles from Durban. The length of track by the old route and the new is practically the same. A branch line connects the new Marshalling Yard on the deviation, a mile from South Coast Junction station, with Clairwood Station, on the Durban–South Coast Line.

It is at present laid as a single line, but the formation for double track has been completed for 12⅛ miles at the end farthest from Durban between Cato Ridge and Cliffdale stations, and for 3½ miles at the nearer end, between Booth Junction and a halt at Mount Vernon. It has been constructed to eliminate the heavy grades and sharp curvature on the old main line, the ruling gradients of this being 1 in 30 in both directions with numerous curves of 300 ft. radius. The principal traffic is coal to the coast, and the deviation provides a practically uniform down grade of 1 in 65 compensated for curvature, only two lengths of grade against down traffic occurring in the line, the maximum grade being 1 in 175. The minimum radius of curve is 500 ft.

The construction of the line entailed some very heavy earthwork, the maximum cutting being 110 ft. deep and the highest bank 116½ ft. There are ten tunnels of a total length of 3,754 yds., the longest being the Delville Tunnel (1,001 yds. long), mostly through granite. The Shongweni Tunnel, also through granite, is 996 yds. long. In spite of the heavy nature of the country passed through, the bridges are few; the only big works of this description being the two crossings of the Umhlatuzan River.

Concrete has been used in the construction of all the bridges, culverts and tunnels, no masonry having been put in.

UMHLATUZAN RIVER VIADUCT.

The viaduct over the Umhlatuzan River, 10½ miles from Durban, is the

FIG. 2.—UMHLATUZAN RIVER VIADUCT, COMPLETED.

Fig 3.—Upstream Entrance to Sterkspruit Culvert.

largest concrete structure on the deviation. Two illustrations of this are given ; *Fig.* 1 is a view taken during construction, and *Fig.* 2 shows the finished structure. The viaduct consists of 7 semi-circular arches of 30 ft. span, the height of rails above ordinary water level being 78 ft. 6 in. and above the lowest foundation 86 ft. 6 in. The foundations were all taken down to rock. The grade across the viaduct is 1 in 110, which was obtained by making the springing level of each pier 4 in. higher than the adjacent one on the down grade side. The arch ring is 2 ft. 6 in. thick, the haunching over the centre of the piers being 12 ft. above springing and brought up on a line tangential to the arch ring and 3 in. above it.

Although the thickness of the arch ring is ample to prevent the line of thrust passing outside the middle third, the arch ring was reinforced with old 45 lb. rail, five 24 ft. lengths of rail being placed in the arch ring 6 in. above the intrados across the centre of the arch, and five rails 16 to 18 ft. long were laid from the springing up on the extrados on either haunch. The object of this reinforcing was to prevent radial cracks due to temperature changes, which often occur in plain concrete arches. Up to the present no cracks have appeared.

An expansion joint was made in the spandrel wall over the centre of each arch. The walls were finished off at rail level and a railing of 5 in. by 2½ in. by ⅜ in. tee-iron uprights with three rails of 1½ in. bore gas piping, giving a total height of 3 ft. 5 in. above the wall, fixed in it. Two refuges on each side of the bridge have been put in above the centre of the second pier from each end. These are corbelled out from the face of the spandrel wall, the projection being strengthened by two lengths of 45 lb. rail reinforcing.

The Durban abutment has ordinary straight wing walls splayed back at an angle of 30 deg. to the face, with a batter of 1 in 9 on the outside face and 1 in 5½ on the back. The Cato Ridge abutment is buried in the bank, the toe of the bank being protected from scour by a retaining wall 14 ft. 3 in. high reinforced by four old rails along its length, and above this the bank is protected by dry stone pitching on a slope of 1 to 1. The centering was built up of 9 in. by 3 in. planks for the struts and ties, and 12 in. by 2 in. for the ring, the latter being formed of three thicknesses breaking joint. Five centres were used for each arch, covered by 1½ in. lagging. Sufficient centering to do three arches at a time was erected. The centres were supported off the springing on hardwood blocks and wedges.

The concrete mix for the arches was 4 parts of broken stone to pass through a 1½ in. ring, 2 parts of sand, and 1 part of cement. For the neat work the proportion was 5 parts of stone to pass through a 2½ in. ring, 3 parts of sand, and 1 part of cement, and for the foundations 6 parts of stone to pass through a 2½ in. ring, 3 parts of sand, and 1 part of cement. Plums not exceeding 1 cu. ft. in size were placed in the foundations, piers, and abutments 12 in. clear from each other, and in the face walls similar plums were placed projecting upwards from the concrete at the finish of each day's work to form a key. The quantity of concrete in the structure was 865 cu. yds. in foundations, 531 cu. yds. in the arch rings, and 3,962 cu. yds. in the rest of the work, a total of 5,358 cu. yds.

BOOTH JUNCTION—CLAIRWOOD BRIDGE.

The other crossing of the Umhlatuzan is between Booth Junction and Clairwood stations. A bridge consisting of ten 40-ft. steel spans, carried on screw pile piers, was already in use for the line to the south coast from Durban, and it was necessary to convert this to a double-line bridge to carry the increased traffic.

This was done by constructing piers of reinforced concrete beside the existing bridge to take the double track founded on reinforced concrete piles 14 in. square, and then moving the girders from the screw-pile piers on to the new piers, a new set of girders to carry the second track being placed in position later.

The foundation for the new piers consisted of 27 piles to each pier, covered with a solid concrete cap on which light piers reinforced with old rails were erected. The maximum height of the piers is 31 ft. The piles were reinforced by $1\frac{1}{4}$ in. diameter steel rods in each corner and a $1\frac{1}{4}$ in. jet pipe in the centre of the pile, the rods being bound together every 9 in. with $\frac{3}{16}$ in. lacing wire and diagonal lacing around the rods and the jet pipe every 3 ft.

STERKSPRUIT CULVERT.

At $32\frac{3}{4}$ miles from Durban the Sterkspruit stream is crossed by a double-line bank 91 ft. above the bottom of the stream, and an arch culvert of concrete, 30 ft. span with semi-circular arch and walls 10 ft. 6 in. high was constructed under the bank. The total length of the culvert is 232 ft. 3 in. The foundation is taken down to rock. The arch ring is 2 ft. 6 in. thick and the haunching was brought up 11 ft. above the springing at the back of the wall. *Fig.* 3 shows the up-stream entrance of this culvert. The total amount of concrete used was 4,810 cu. yds.

HAMMERSDALE SPRUIT BRIDGE.

Fig. 4 is a view of a double 30 ft. arch bridge $35\frac{3}{4}$ miles from Durban over the Hammersdale Spruit. This bridge was originally constructed for a single track with the spandrel walls 3 ft. below formation level. When it was decided to double the track it was found that sufficient room for the two tracks could be obtained by raising the spandrel walls to 1 ft. above formation level, and this was done. The walls are thickened and reinforced by old rails and further stiffened by cross walls on the top of the arches, which were tied into the spandrel walls. The wing walls on each side were raised by rough rubble masonry and the bank was pitched above this so as to stand at a steeper slope.

CATO RIDGE CULVERT.

Fig. 5 shows the outlet of a 15-ft. span arch culvert 41 miles from Durban. This was built on the top of a waterfall, the arch ring being 1 ft. 6 in. thick (semicircular), and the walls 8 ft. high. All the tunnels are lined with concrete, the inside dimensions being 15 ft. wide and 16 ft. high above rail level, and the roof is a semi-circular arch. The thickness of the lining varied from 9 in. to 2 ft. 9 in. depending on the nature of the strata passed through.

In order to prevent slips in some of the cuttings it was necessary to construct concrete toe walls at the edge of the formation. These were generally rein-

FIG. 4.—HAMMERSDALE SPRUIT BRIDGE.

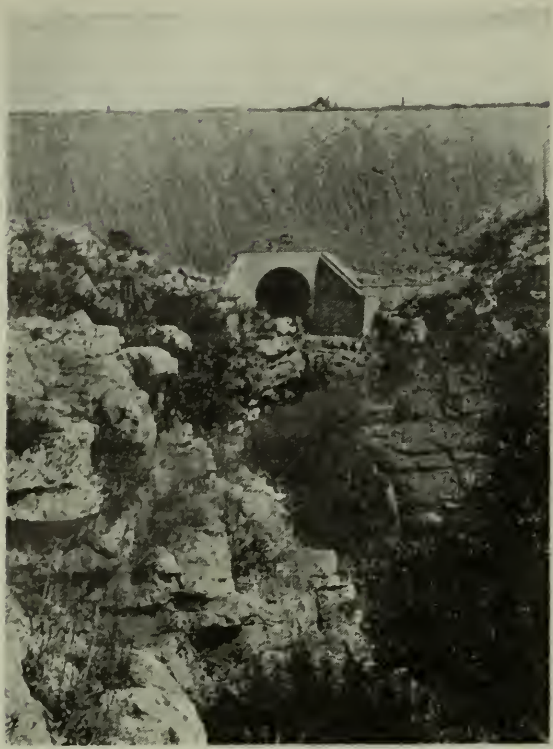


FIG. 5.—OUTLET OF CATO RIDGE CULVERT.

forced with old rails, and in some cases strutted across under formation by concrete struts reinforced with rails and butting against the toe of the other slope of the cutting. Drystone backing well blended with ashes was then built in behind the wall, and through this stone pipe-drains were laid to carry off any water accumulating.

All the smaller culverts, which were built to the standard types of the South African Railways, were built in concrete. The standard specification for concrete is that the broken stone should pass through a 2½-in. ring; the general mixture being 5 or 6 parts of stone to 3 of sand and 1 of cement. Excellent stone was obtainable all along the line, either of hard sandstone or quartzite. Nearly all the mixing was done by hand with native labour.

There are a number of retaining walls of concrete protecting the banks where the line runs along river banks. These were also constructed of concrete to standard dimensions.

Concrete has also been used for the construction of reservoirs for locomotive water supplies. Two of these, each holding 100,000 galls., have been put in, one supplied by gravity and the other by pumping from adjacent streams. These reservoirs are about 36 ft. sq. and 16 ft. deep, the walls and floors being reinforced with tram rails, 16 lb. section; the walls are 18 in. thick at the top, with a batter of 1 in 12 on the inside face. The reservoirs are placed in excavation for the greater portion of their depth, and the portion above ground is supported by banking.

Circular tanks, 12 ft. diameter, to hold 6,000 galls. were placed at each house where a water supply was not obtainable to catch the rainwater from the roof. These tanks were built with 9-in. walls reinforced with tram rails bound with lacing of wire and plastered inside with a coating of cement.

A large quantity of concrete was also used in the foundations for the houses for the staff operating the line, for floors of goods sheds, and various other structures.

A trial was also made of building several sets of quarters of plates of concrete made with ashes. The standard size of plate is 3 ft. by 9 in. by 3 in. thick. The outside walls are built with double plates with a 3-in. cavity between tied together with ordinary crimped wall ties of galvanised iron; the outside of the walls was plastered with cement mortar. The results were very satisfactory, both from the point of view of economy, appearance, and comfort.

The work generally was carried out by contractors under the supervision of the construction engineers. We are indebted to Sir W. W. Hoy, General Manager of the South African Railways and Harbours, for these particulars and the accompanying illustrations.

MUNICIPAL BATHING POOL DESIGN AND CONSTRUCTION.

By CHARLES ELLIOTT.

In view of the growing popularity of outdoor bathing it is not surprising to find park improvements in many cities have in recent years included the provision of outdoor bathing pools. Of the numerous types of pool installed, the rectangular basin of concrete construction stands out with especial prominence. Concrete construction is ideal for bathing pools. It ensures strength, watertightness, freedom from expensive maintenance, and absolute permanence. Well-made concrete being dense and impervious, a pool constructed of this material may also readily be kept in sanitary condition, thereby adding very greatly to its attraction and popularity.

In selecting a site for the outdoor bathing pool, a location should if possible be chosen where natural drainage of the soil is good. The site should also be such as to permit of the pool bearing an harmonious relation to surrounding structures or landscape details. Attractively-arranged surroundings add enormously to the enjoyment of bathers, and furnish a pleasant contrast to the sometimes depressing surroundings of the indoor swimming bath.

The dimensions of the outdoor bathing pool will, of course, be largely governed by local conditions. In the accompanying drawing a design is suggested for a small rectangular pool 60 ft. long and 20 ft. wide. Any change in the dimensions given would naturally involve modification of certain details of the design, such as increasing or decreasing the quantity of reinforcing utilised, and so on. The design herewith reproduced (*Fig.* 1) has been extensively adopted in the United States, in which country considerable experience in bathing-pool construction has been obtained.

The walls of this pool are designed on the assumption that the soil has a bearing power of not less than 4,000 lb. per sq. ft. Should the bearing power be less than this figure the footings would require modification accordingly. In

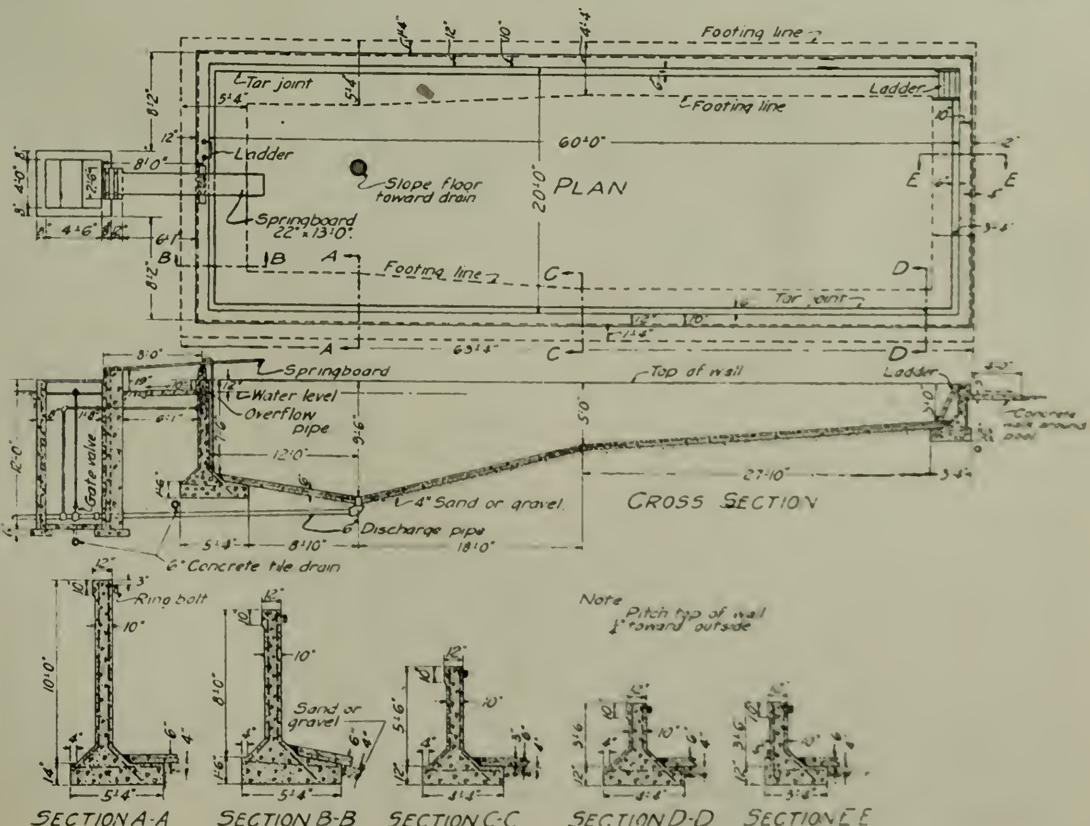


Fig. 1.—Design for an Outdoor Bathing Pool.

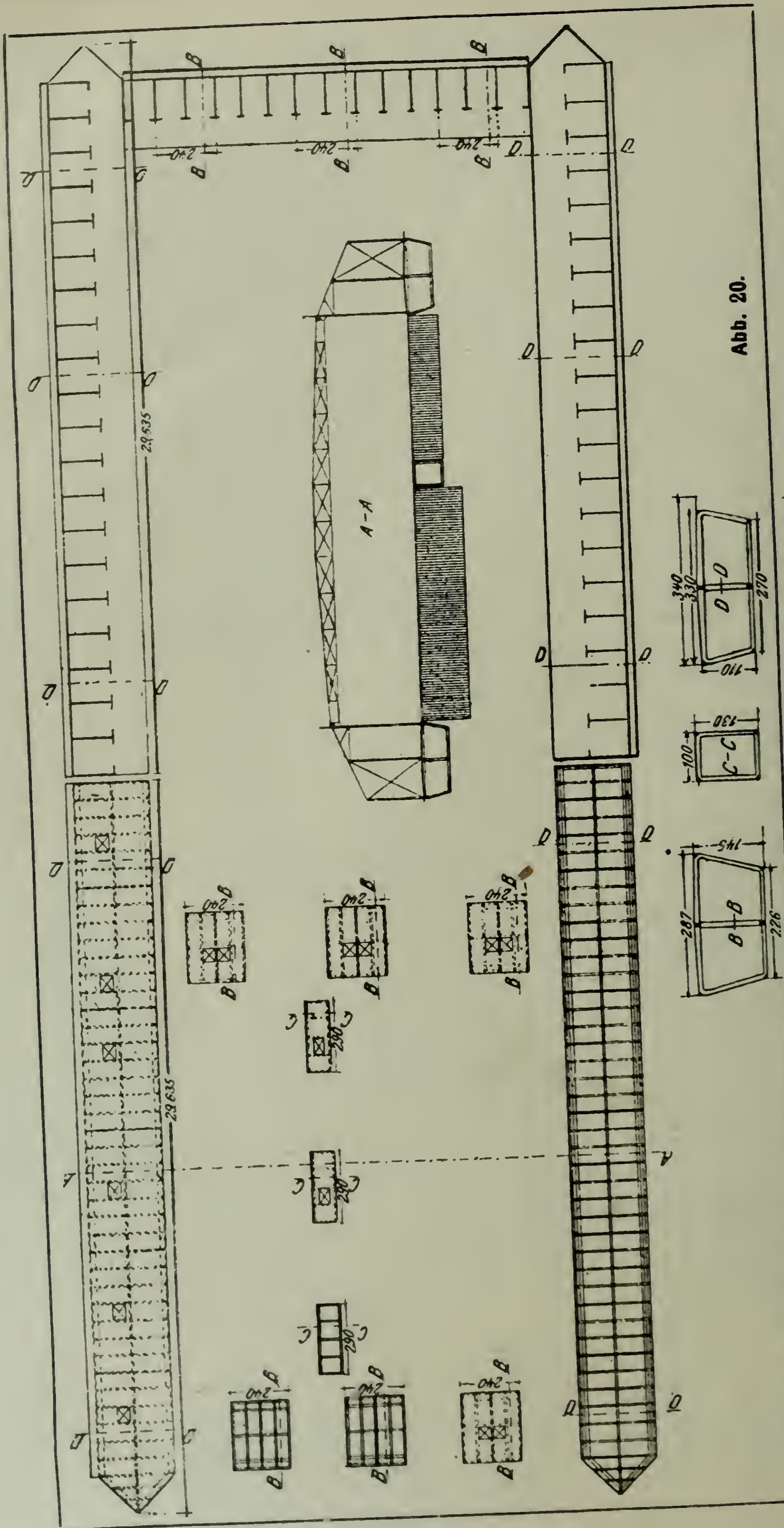


FIG. 2.—SWIMMING BATHS BUILT ON PONTOONS. (See p. 735.)

excavating for the footings the trench should be made large enough to provide sufficient excavated space, after setting up the form for the exterior of the footings, to receive the 6-in. concrete drain tile laid around the entire exterior of the footing. The lowest point of this drain is connected with another tile line leading to a convenient outlet situated low enough to permit of uninterrupted drainage. After footing forms have been set up and braced, reinforcing for the wall should be erected, being assembled by wiring at all intersections, and temporarily stayed in position by supports placed above the footings. Reinforcement should also be temporarily secured to vertical supports so that it will remain correctly assembled in proper position while concrete is being placed in the forms.

The footings should be built up to the bottom of the fillet, at which level a notch 2 in. deep and 4 in. wide should be formed in the concrete by forcing a slightly bevelled piece of 2 by 4 timber into the soft concrete and allowing it to remain until the concrete is hardened. The notch or groove formed in the concrete will key the wall into the footing and increase the watertightness of the construction joint. In addition to the notch, the concrete should be left level and roughened. Before the concrete for the wall is placed, the surface of the footing upon which the wall will rest should be scrubbed clean, drenched with water, and flushed with a mortar composed of one sack of Portland cement to 2 cu. ft. of sand. This mortar coat should not exceed ½ in. thickness, and before it has hardened the concrete for the wall should be placed. Whenever work is stopped, so that the concrete will have hardened before the next layer can be placed, the same precautions should be taken to ensure a watertight joint.

After the concrete in the footing forms is twenty-four hours old, forms may be removed and the timber used for the wall forms, the forms being completely built after the temporary supports carrying the reinforcing at the bottom of the fillet have been removed. The upper ends of the reinforcement should then be temporarily stayed to the forms to hold the rods in correct position while concrete is being placed. Wall forms should consist of sound timber planed to a uniform thickness, either tongued and grooved or with bevelled edges to make tight joints and prevent leakage of mortar. Special attention should be given to bracing forms and to wiring them together to prevent any sagging or deformation. The upper ends of the reinforcement should then be stayed to the forms to hold it in correct position while concrete is being placed. Provision should also be made to hold the reinforcement at the proper distance from the face of the form.

Fig. 5.—Bath during Erection, showing Constructional [illegible]. (See p. 7[illegible].)

If only bank-run gravel is available the material must be screened by separating it into at least two parts, the sand being that material which will pass through a screen having four meshes to the linear inch, the pebbles being that material which will not pass this screen and which ranges from ¼-in. particles up to those having a maximum dimension of 1 in. The concrete mixture for the entire construction should be one sack of Portland cement to 2 cu. ft. of coarse, clean, well-graded sand, and 3 cu. ft. of hard, clean, well-graded pebbles or broken stone. Water used for mixing concrete should be clean and free from oil, alkali, acids, and vegetable or other organic matter; and enough water should be used to produce a concrete of jelly-like consistency.

Concrete should be placed in layers not deeper than 9 in., each layer being well puddled with a rod and the forms rapped with wooden mallets. This helps to settle the concrete properly in the forms, completely surrounding the reinforcement and working into difficult corners. It also tends to reduce air and sand pockets, and, by forcing the mortar against the forms, produces a dense, smooth, watertight surface. The forms should be well braced to prevent bulging due to pressure of the wet concrete. Under favourable weather conditions wall forms may be removed after thirty-six hours, but the back filling should not be done until the concrete is at least four weeks old, nor should the pool be filled with water for at least four weeks after the last concrete has been placed. Any air or pebble pockets on the interior surface of the wall after forms have been removed should be at once filled with a 1 : 2 cement-sand mortar.

After wall forms have been removed the soil upon which the floor is to rest should be graded to proper level and slope, a 4-in. sand cushion placed and solidly compacted by rolling and tamping, and wedge-shaped wooden strips placed around the edge of the inner fillet to form the joint between floor and walls. The concrete for the floor should then be placed, reinforcement being laid 3 in. from

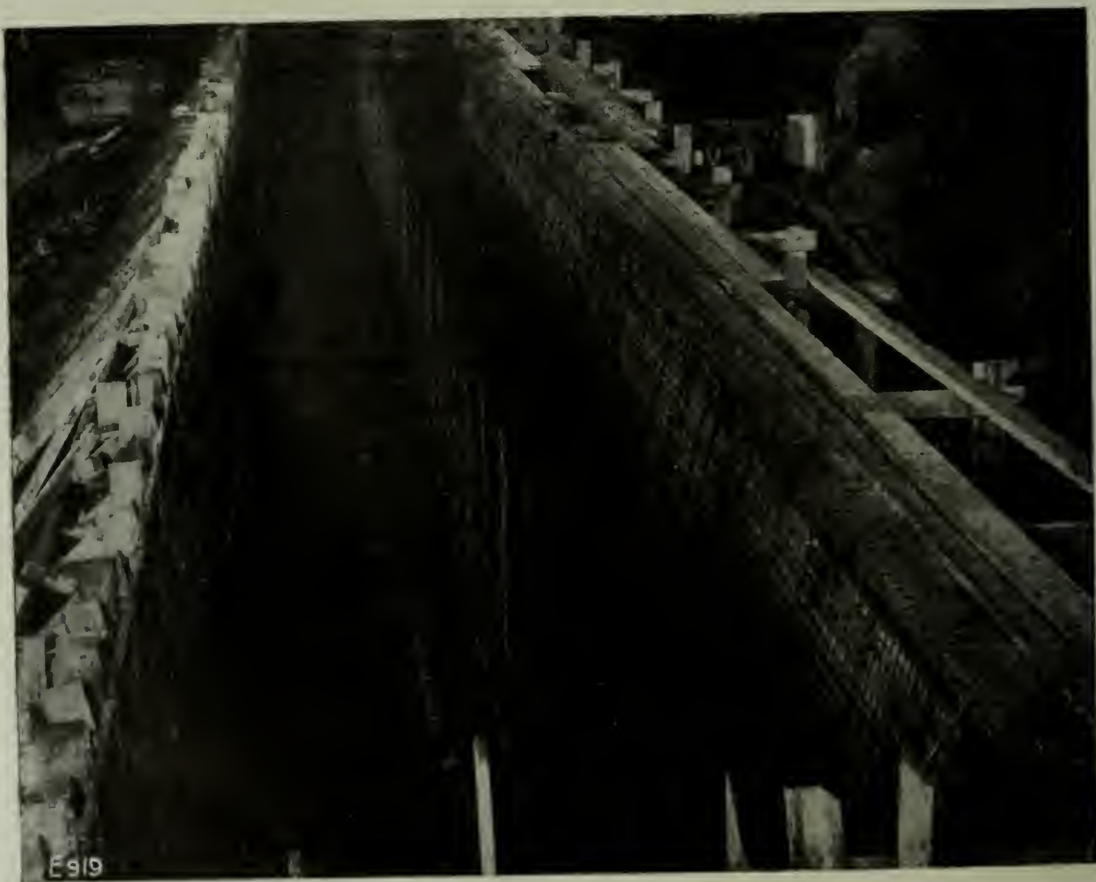


FIG. 4.—REINFORCEMENT OF PONTOON. (*See p.* 735.)

Fig. 5.—Large Pontoon ready for Launching.

the top surface, as shown. The concrete should be struck off by using a wooden strikeboard and given its final finish by hand floating with a wood float. This plan contemplates continuous concreting of the floor. If it is impossible to carry on the work in this manner provision must be made for joints that will make the floor consist of two or more slabs.

For at least ten days after wall forms have been removed the concrete should be protected from sun and wind by canvas, in addition to which the covering and the concrete itself should be wetted down several times daily. After concreting of the floor is finished the work must be protected to prevent too rapid drying out of the concrete. Protection should be continued for at least ten days, after which the strip at the outer edge of the floor may be removed and hot tar or asphalt poured into the space between floor and fillet to seal the joint.

Overflow and discharge pipes should be provided for as shown ; the inlet pipe is not indicated, as its location depends upon local conditions. It is particularly necessary that for inexpensive operation the facilities for filling and emptying the pool be as simple as possible. The pool should be located so that gravity flow will empty it when necessary to change the water for cleaning the pool or for other reasons.

The design which has been described has been made with every regard for economy of materials and equal consideration for efficiency of design. The following approximate estimate will enable one to determine the probable cost as influenced by the price of materials in the particular locality in question:—

Portland cement . . .	15 tons
Sand	50 cu. yds.
Pebbles or broken stone .	74 cu. yds.
Reinforcement . . .	$1\frac{1}{2}$ tons
Concrete tile	180 ft. of 6-in.
Timber.	6,000 ft.

As no bathing pool is complete without a spring-board, provision should be made for one at the deep end of the pool. It may be anchored to the wall of the manhole containing discharge valve, etc., as indicated, or to a separate block of concrete. The suggested design shows two ladders, one near the spring-board and the other near the corner at the shallow end of the pool. By embedding short piping in the top of the wall and floor when the concrete is placed, and later fastening the ladder to these, the work of installing the ladder will be made very simple. To avoid slipping, the top surface of the pool wall should be left rough, and for the safety of swimmers a hand-hold should be provided, encircling the pool. Ring bolts should be embedded near the top of the inside wall as indicated. These should be spaced about 10 ft. apart, and through them may be run a rope or pipe.

FLOATING BATHS.

In Germany, America, and more recently Holland, swimming baths have been constructed on pontoons in such a manner that they rise and fall with the

Fig. 6.—Swimming Bath Completed.

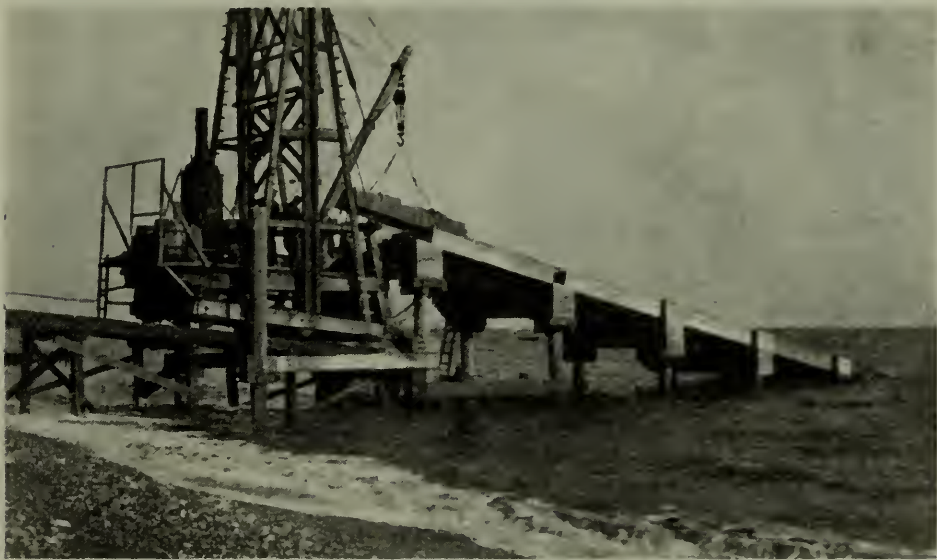
variations in the water-level. The largest, which is at Kampen, is shown in the accompanying illustrations. The pontoons are of reinforced concrete, which was found to be 10 per cent. cheaper than if made of iron and to require far less expenditure on maintaining them in good condition.

A notable feature of this structure is its great length and the use of four very large pontoons in addition to the twelve smaller pontoons of more usual dimensions. The total length of the swimming bath is over 200 ft. and its width 76 ft. Along each side and parallel to the stream are two large pontoons, and at each end are three smaller ones. Three more small pontoons, united below the water line by iron girders, divide the bath into two parts: the smaller one (57 ft. by 55 ft.) for learners and the larger one (103 ft. by 55 ft.) for more experienced swimmers. The smaller bath is still further divided into two portions by three small pontons, a suspended cage being supplied to each portion—a shallow one for beginners and a deeper one for experienced swimmers. Galleries are provided for visitors.

The larger pontoons are united by iron lattice work (*Fig.* 3), which also serves to support the galleries. The dressing cabinets and other offices are on the large pontoons. The large pontoons are each 100 ft. long, 10 ft. wide, and 4 ft. deep, and were built in accordance with designs found successful for lighters and other strong craft. The general arrangement of the reinforcement is shown in *Fig.* 4. The ends of the pontoons which are in contact are rectangular, but the opposite ends are pointed, the sides meeting at an angle of 45 deg., and when completed appear as shown in *Fig.* 5. To prevent sinking in the event of a leak or a severe blow damaging the sides, these pontoons consist of a series of seven closed chambers (*Fig.* 2), with a concrete roof or deck over all. They are strengthened by a series of transverse ribs, spaced uniformly, and a longitudinal web. The smaller pontoons are similar in design. All the pontoons were built on long stocks, from 6 to 8 weeks being required for their construction and a further 3 weeks for hardening.

NEW REINFORCED CONCRETE LIFEBOAT STATION AT SELSEY.

Looking Seawards along the Keelway.



Stepped Gangway Panel being placed in Position.

Looking up the Slipway: Stepped Gangway Panel being placed in Position.
[This slipway for the lifeboat at Selsey, Sussex, was completed early this year.]

[Mr. J. B. L. Meek, M.Inst.C.E., Engineer to the Corporation.

Reinforced Concrete Arterial Road at Manchester. (See p. 739.)

CONCRETE ON ARTERIAL ROADS.

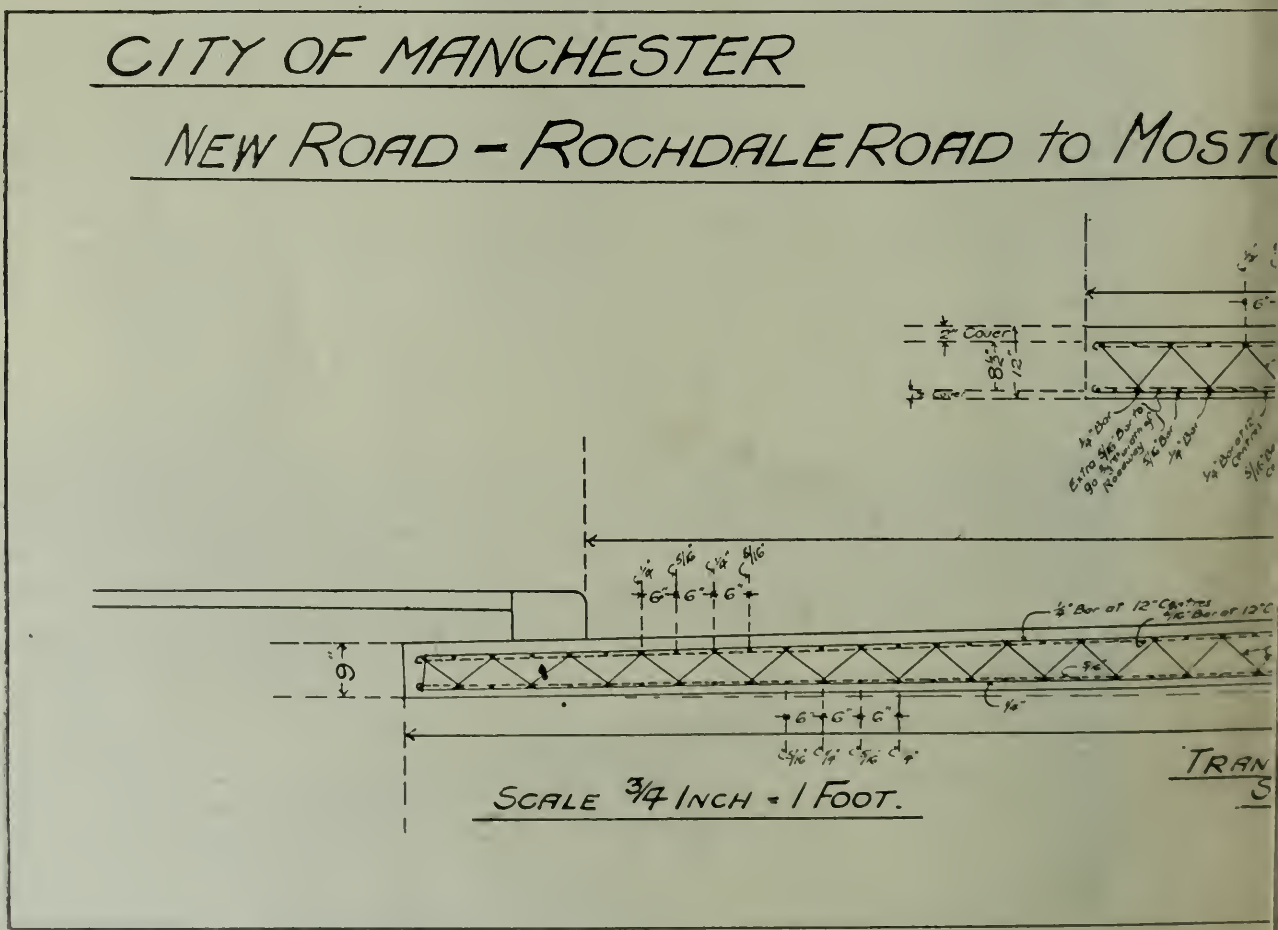
The construction of arterial roads takes a prominent place in the town-planning schemes of the Manchester Corporation, and many of these new roads are being built entirely of concrete and reinforced concrete with no top-dressing. The Corporation has taken a very long-sighted view in this connection, and the new main roads are being constructed of widths of 80 ft. and 100 ft. between fences with a view to possible future requirements. When it was decided to commence the work, the question of the materials and methods of construction was influenced by the necessity for spending as much of the cost as possible on labour and as little as possible on materials, in order to relieve the prevailing unemployment. It was therefore decided in the case of the 100-ft. roads to complete all excavation and filling to formation level for the full width of the road but only to pave one carriageway and one footpath, so that the roads might be used when complete, leaving the other footpath and carriageway ashed and rolled until such time as the traffic justified a permanent paving for the whole of the 100 ft. The drawing on pp. 740–741 shows a cross-section of these roads as they are now being built. In the case of the 80-ft. roads the whole of the 50-ft. carriageway and both footpaths are being completed.

Mr. J. B. L. Meek, M.Inst.C.E. (Engineer to the Corporation), in an article in a contemporary, states that some time previous to the commencement of these roads the Corporation laid down a concrete road in another part of the city in six experimental lengths, and as observations of this road indicated that a concrete surface would be successful in the case of the new road, this method of construction was accordingly adopted. The roads are not all reinforced, as reinforcement has only been used in the case of bad foundations or on embankments or where trenches have recently been opened across the roads to provide connections for the services from one footpath to the other. All the connections required by the various services (gas, electric lighting, water and sewers) were laid before the work of concreting commenced and reinforcement was used over the trenches. The method of constructing the concrete carriageway is the same on all roads. Where there is a sound foundation capable of supporting from 30 cwt. to 2 tons per sq. ft., which is generally the case, the method of constructing the carriageway is as follows: 3 in. of ashes or clinkers are rolled and consolidated on the natural foundation to form a bed for the concrete. On this bed, after well watering, the concrete is directly placed. The total thickness of the concrete is 7 in., laid in two courses, the bottom course being 5 in. in thickness and the top course 2 in. The proportions of concrete for the bottom

Concrete Road at Manchester in Course of Construction.

course are approximately 5 parts stone, $2\frac{1}{2}$ parts sand, and 1 part Portland cement, while for the top course the proportions are 2 parts stone, 1 part sand, and 1 part Portland cement. The voids in the stone were frequently measured and the proportions adjusted to obtain as dense a mixture as possible. The stone in the bottom course is a good hard stone from $1\frac{1}{2}$ in. to $\frac{1}{4}$ in. gauge ; the sand for this course is clean and free from organic matter but not very sharp. For the upper course the stone consists of approved granite from $\frac{3}{4}$ in. to $\frac{1}{4}$ in. gauge, and good sharp sand or granite grit is used. All the concrete is hand-mixed and deposited in alternate bays, as shown in the illustrations. When concreting started on a length of road one gang proceeded to lay alternate bays, and in from ten to fourteen days another gang followed and filled in the bays not completed. In laying the concrete the bottom and top courses are laid practically simultaneously in order that the whole thickness of the concrete might set together in one homogeneous mass ; and when once concreting has been commenced on a bay no cessation of work is allowed until the work is completed. The top surface of the concrete is finished off to the required levels and falls with a wooden or steel-shod template.

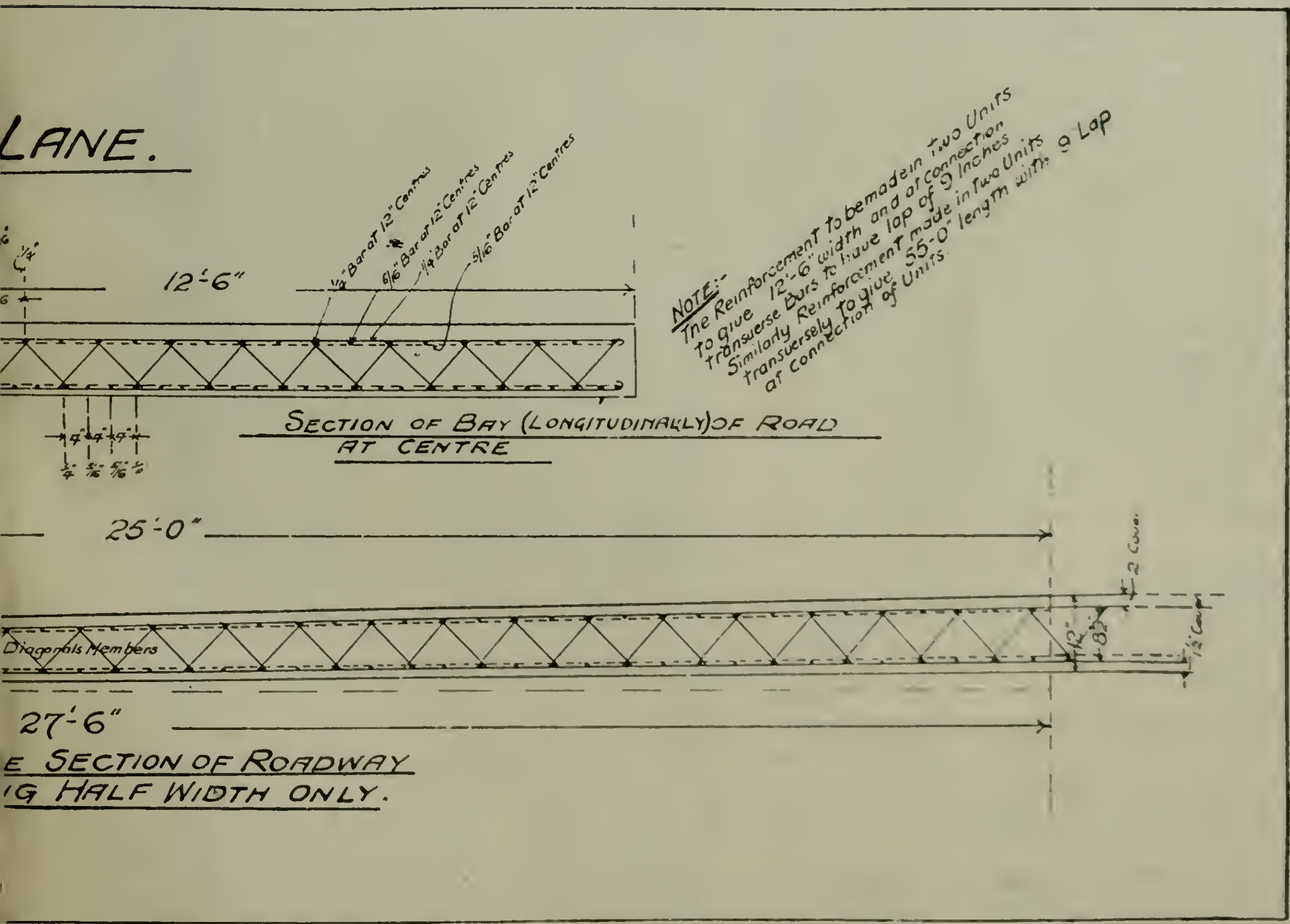
Where cross trenches have recently been excavated in the carriageway foundation, single-mesh reinforcement is used. In the reinforced concrete surface on embankments and bridge approaches, the banks are first consolidated by watering and rolling and the reinforced concrete structure placed on the well-rolled foundation of ashes. In these sections provision is made for tension in the top and bottom surfaces, and also for shear, and Walker-Weston patent double-layer interlocking reinforcement, which has been specially designed to make provision for these stresses, is being used. On these sections the depth of the concrete is 9 in., and the carriageway is extended 1 ft. 6 in.



REINFORCED CONCRETE

Showing the Peat on which part of the Reinforced Concrete Roads at Manchester are Built.

under the kerb at each side of the road in order to give support to traffic travelling close to the kerb. As with the sections on more solid foundations, these portions are constructed in bays. Concrete is first laid to a depth of 1 in., and on this is placed the reinforcement, which is 6 in. deep. Concrete is well-worked



Roads at Manchester.

round the reinforcement, which is covered with concrete to a depth of 2 in. between its upper surface and the surface of the road.

One length of 80-ft. roadway passes for a distance of a mile through a peat bog varying in depth from 5 ft. to 10 ft. below formation level. Here the peat has been taken out for a depth of 1 ft. 6 in. and the space filled with ashes and clinkers, rolled. On this surface the concrete slabs reinforced with Walker-Weston reinforcement are built, each slab being continued for 2 ft. 6 in. beneath the kerb on each side. The thickness of these slabs is 12 in. at the centre and 9 in. at the edges, with reinforcement 9 in. deep at the centre and 6 in. deep at the sides.

The kerbs and fence posts used on these roads are all made of concrete in the Corporation's depôt adjoining the site, the posts being reinforced with four ¼-in. steel bars. The paving flags for the footpaths are all of concrete, manufactured where required on the finished road surfaces.

Some pieces cut out of the road for the full depth have been subjected to tests, which showed that after being kept fourteen days in a dry room and afterwards immersed for eighteen hours in water, the absorption was approximately 3 per cent.

Some sections of these arterial roads have been in use for over a year, and other sections of all-concrete roads in Manchester have been open to traffic for two years; in neither case, states Mr. Meek, does the surface show any serious sign of wear.

DEFECTIVE CONCRETE TILES.

By ALFRED B. SEARLE.

The present shortage of tiles is such that purchasers are sometimes content—as in war-time—to accept without question concrete tiles of inferior quality, but this state of affairs cannot continue indefinitely and manufacturers and merchants should see that only good concrete tiles are offered for sale.

Concrete tiles are made of cement, sand, a colouring material and water, and sometimes oil is used to facilitate the removal of the tiles from the mould. The manufacture of asbestos tiles, in which asbestos is used instead of sand, is a separate industry and requires an entirely different procedure.

Cement.—The cement should be Portland cement of a standard quality, as no other binding material is so satisfactory.

Sand.—The sand should be a clean, sharp quartz sand with grains of many sizes, but none more than ⅛ in. diameter, or the smooth surface of the tile will be disturbed. Slags and other crushed materials should not be used, particularly if they contain sulphur compounds, as tiles made from them are very liable to crack and become porous. If ground slag must be used it should previously have been very thoroughly weathered, so as to wash out all detrimental impurities.

Pigment.—The pigment or colouring agent must be free from the harmful ingredients present in the cheaper colours, or the tiles will be of small value. The iron oxide used for red tiles must be free from gypsum and other soluble or semi-soluble salts. Ochre and zinc yellow used for yellow or buff tiles should be free from particles easily removed by water, and particularly from soluble salts. The umber used for brown tiles should be similarly free from soluble materials. The ultramarine, green, and chrome-green pigments often produce a white scum after the tiles have been in use for some time. This indicates faulty manufacture of the pigment and imperfectly washed colours. Blue tiles are usually coloured with ultramarine blue; care should be taken that it is of good quality and not diluted with any objectionable material. Whiting stained with an aniline blue should on no account be used. In black tiles the pigment is usually lamp black or manganese dioxide; the former sometimes contains pieces of other material which swell when wetted and cause the tiles to crack, whilst the latter—in the form of Weldon mud—often contains objectionable soluble salts. As all pigments (except ultramarine) reduce the strength of the concrete to which they are added they should be used as sparingly as possible. As the material in the interior of each particle of pigment is of no use for colouring purposes, the finer the pigment is ground the greater will be its colouring power and the smaller will be the quantity required. Some tile manufacturers grind the pigment with some of the sand, and by this means increase its covering power and also ensure a more uniform distribution of the colour.

WATER.—The water should be as soft as possible, but water of moderate temporary hardness yet free from other soluble salts is not objectionable.

OIL.—The oil used in the moulds is frequently a source of trouble, particularly when unreasonable attempts are made to use a very cheap oil. Only mineral oils are suitable for this work, as animal and vegetable oils react with cement. The film of oil should be as thin as possible—it is only required to keep the concrete out of direct contact with the metal—but it must be a complete film. If any part of the metal be not covered with oil the concrete may adhere to it, and the tile will then have to be removed with undue force. Such tiles should never be sold, as whilst the damage done to them may be invisible at first it will show itself later by allowing rain to penetrate the roof.

MANUFACTURE.—The manufacture of concrete tiles requires both skill and patience. It should be carried on in a room free from dust and draughts, as the former will spoil the appearance of any tiles on which it settles whilst the latter may cause almost invisible yet objectionable cracks, or the still more serious "hair cracks" which are difficult to avoid when using so fat a mixture as is generally required for tiles.

The customary proportions of cement and sand are 1 : 3, which may be changed to 2 : 5 if much colouring matter is to be added, though the latter should seldom exceed 12 per cent. The addition of trass is sometimes made to increase the permeability of the tiles. The wet mixture should be of suitable consistency, neither too soft nor too dry, the best condition being that resembling moist garden soil.

The paste is placed in oiled steel moulds and subjected to a slight pressure. The resulting tiles should then be laid aside for a fortnight, during which time they should be thoroughly and repeatedly wetted. They must not be kept in a hot room, a temperature of 65 deg. F. being the highest to which they can be exposed with safety ; and even at this temperature they must be kept very wet, as premature drying is a common cause of cracking. After a fortnight's storage under wet conditions the tiles should be stored in a cool dry place for a further fortnight. The older the tiles before they are used the better will be their quality, as they improve with age. Some firms refuse to allow tiles to leave their works until they are at least three months old.

When coloured tiles are produced in which the colour is only applied to the surface it is important to secure its proper adhesion. This can usually be best effected by adjusting the pressure applied to the mould. Unevenly applied pressure often causes flaking when the tile is in use. The application of the pigment with a brush is seldom satisfactory.

Properly made concrete tiles will last as long as tiles made of any other material.

USEFUL ARTICLES MADE OF CONCRETE.

Many articles in common use may advantageously be made of concrete in moulds made of sheet iron strengthened with angle iron. Among others are the following :—

(*a*) *Sinks*, with or without legs, can be made of any size and thickness, though 3 ft. × 2 ft. × 6 in. with the walls 2½ in. thick is usually the most convenient.

(*b*) *Flues* and *short pipes* useful for a variety of purposes may be made in cylindrical moulds.

(*c*) *Air-bricks* and *vents* are readily made in a mould consisting of four sides and a base with a suitable core.

(*d*) *Tiles* for fountains, pumps, etc., are usually made in two-piece moulds.

(*e*) *Feeding troughs* for cattle, sheep and pigs are made in the same way as sinks, but are deeper for greater convenience.

(*f*) *Gutters* are made out of simple moulds, the bottoms of which are shaped to correspond to the interior of the gutters.

The forms must be strong and well-designed, and are usually purchased ready made from a dealer.—*Beton u. Eisen.*

CEMENT NOTES.

By Our Special Contributor.

Misuses of Cement.

THE "misuse" of plaster or concrete is usually concerned with the addition of certain materials to the cement or mortar with the object of producing certain effects. The modern rotary-kiln cements which are quite free from floury underburnt material—differing in this respect from the fixed-kiln cements of twenty years ago—are described by the plasterer as "short," i.e., lacking in plasticity when mixed and therefore not easy to manipulate when plastering. Often the plasterer's remedy is to mix lime with the mortar, and there is no doubt that a more "buttery" mortar is so obtained. This is, however, an expedient which cannot be recommended, because lime has a tendency to retard the hardening and decrease the strength of cement mortars, while there is also considerable risk of inequality of mixing, leading to soft places in the plaster containing excess of lime or nodules of undiluted lime. A more reliable means of obtaining a plastic mortar is to use a finely-ground cement.

The addition of washing soda for the purpose of hastening the setting of cement mortar is well known and often used, more particularly by pipe-jointers. If the proportion of soda added is small there is no scientific objection to its presence in the mortar, but the danger lies in the varying effect of soda on the setting properties of cement. The same proportion of soda that would convert one slow-setting cement into a medium-setting cement would cause another cement—apparently similar—to have instantaneous setting properties, so that unless a series of experiments be conducted for each consignment of cement and under each condition of atmospheric change—a procedure foreign to the average concrete worker—the practical results of the use of soda are apt to be so variable as to nullify its useful effect. Again, this is an unnecessary expedient, because medium-setting cements can be obtained from most cement manufacturers upon demand.

The opposite effect of soda addition is sometimes sought by concreters, and this is obtained by adding alum to the mortar; more particularly is this done when applying patches to old concrete. Plasterers have discovered that the initial shrinkage which is the usual cause of separation of new concrete from old can be prevented by allowing the mixed concrete intended for patching to stand several hours before application to the old concrete, and unless this concrete is carefully watched and remixed at intervals it sets and becomes unusable. Hence the custom of mixing the concrete overnight with the addition of alum, which retards the setting to a considerable degree and ensures that the concrete is plastic enough to spread the next morning. Alum is an undesirable addition, because it adds to the sulphur content of the cement and may lead to subsequent disintegration of the concrete; the alternative is to obtain a very slow-setting cement from the manufacturer and to have labour available to remix the concrete to prevent hardening before it is used for patching. It will be noted that this method of using concrete—i.e., "killing" the set—is at variance with the recognised rules, which stipulate that the setting must not be interfered with, but the results in connection with patching old concrete have justified the divergence from the correct practice.

Hot Cement.

THE words "hot cement" as commonly used are capable of three meanings. They may imply a cement which is hot to the touch, a cement which is quick-setting, or a cement that is unsound and cracks or expands after setting. Cement that is quick-setting or unsound is described as hot on the supposition that these characteristics are derived from its newness or freshness from the kiln, while the prejudice against a cement that is tangibly hot is based upon the presumption—usually false—that a cement fresh from the kiln is liable to be unsound.

Cement as ground into the bins or silos of cement factories is always warm and frequently hot, because the energy expended in grinding the cement is partly dissipated in heat. During the grinding of cement its temperature will generally rise by as much as 50° F., and if the clinker being ground is not completely cooled on leaving the kiln it is quite possible for the cement in the manufacturers' store to have a temperature of 150° F. or more. When the cement store takes the form of an enclosed silo 50 ft. high the cement has little chance of cooling, and it may reach the consumer with a temperature of 120° F.

Beyond the physical discomfort of the men handling hot cement there is no valid objection to its use. The manufacture of cement is now so carefully controlled that hot cement obtained by grinding clinker direct from the kiln is perfectly sound and can be made as slow in setting as may be required. It is, indeed, hourly practice at all cement works to test hot cement straight from the mills for soundness (boiling water test) and setting time, and both tests are required to be normal without exception in all well-regulated factories. The effect of the heat of the cement at 120° F. in a 1 : 2 : 4 concrete would be negligible, as the temperature of the whole mix would only be raised by about 2° F., and only if such a cement were used neat would there be a tendency for it to be quicker setting than if it were cooled. Hence users of reputable brands of cement need have no misgivings in using the cement in a hot condition.

The application of the term "hot" to a quick-setting cement is a misnomer which may have had its origin in the fact that quick-setting cements show a decided rise in temperature during setting. This was at one time thought to be an indication of a dangerous cement—as witness the now discredited "rise in temperature" or "marmalade pot" test—but has since been found to have possibilities of advantage in preserving concrete from the effect of frost (*vide* recent article in this Journal on "Concreting in Winter").

Unsound cements were described as hot in the past because they improved with aeration or cooling. British-made cements of this character are now rarely encountered and the aeration of modern cements is not only unnecessary but inadvisable because the finely-ground cements of to-day quickly absorb moisture from the atmosphere and become weakened thereby.

STANDARDISATION IN PROPORTIONING CONCRETE.

We give on the following pages the remainder of the tables for the proportioning necessary to produce concretes of different compressive strengths, which were commenced in our last issue, together with an explanatory article. These tables are the result of tests undertaken at the Structural Materials Research Laboratory of the Lewis Institute, Chicago, by Mr. Duff Abrams (Professor in Charge of the Laboratory) and Mr. Stanton Walker (Associate Engineer), and are reprinted from Bulletin No. 9 of the Laboratory.

The following precautions are to be observed in the use of tables :—

1. If the proportions to be used in the work are selected from the tables, without preliminary tests of the materials, and control tests are not made during the progress of the work, the mixtures in bold-faced type should be used.

2. Strengths were based on 28-day compression tests of 6 by 12-in. concrete cylinders puddled in the forms, cured in a damp place at normal temperatures and tested in a damp condition. Allowance must be made for lower strength resulting from temperatures below normal.

3. Portland cement should be up to standard specifications.

4. Aggregate should be clean, structurally sound, and graded in size between the limits shown in the tables.

5. Concrete should be mixed at least 1 minute in a batch mixer.

6. In comparing the strengths of concrete specimens made on the work with the values in the tables, it is important that tests be made in accordance with standard methods.

7. The quantities of materials were based on measurements in the laboratory, using dry materials rodded or puddled into the measure. Waste was not allowed for.

8. The slump test should not be too strictly interpreted.

9. Proportions and quantities of materials may be interpolated for concrete strengths, aggregate sizes, and consistencies not covered by the tables.

[In the tables giving the quantities of materials required to produce concrete of a given strength, it should be noted that the standard American barrel contains 376 lb. or four bags of 94 lb. each.]

PROPORTIONS FOR 3,000 LB. PER SQ. IN. CONCRETE.

[Based on 28-day compressive strength of 6 by 12 in. cylinders. Proportions are expressed by volume as follows: Portland cement : fine aggregate : coarse aggregate—Thus 1 : 2·6 : 4·6 indicates 1 part by volume of Portland cement, 2·6 parts by volume of fine aggregate, and 4·6 parts by volume of coarse aggregate.]

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes: 0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-3/8 in.
None	½ to 1	1:1.5	1:1.7	1:2.0	1:2.3	1:2.7
	3 " 4	1:1.2	1:1.4	1:1.7	1:1.9	1:2.3
	6 " 7	**1:0.9**	**1:1.0**	**1:1.2**	**1:1.4**	**1:1.6**
	8 " 10	1:0.6	1:0.6	1:0.7	1:0.8	1:0.9
No. 4 to ¾ in.	½ to 1	1:1.3:2.7	1:1.5:2.6	1:1.7:2.5	1:1.9:2.4	1:2.3:2.1
	3 " 4	1:1.0:2.3	1:1.2:2.2	1:1.4:2.2	1:1.6:2.0	1:1.9:1.8
	6 " 7	**1:0.7:1.7**	**1:0.8:1.7**	**1:0.9:1.7**	**1:1.1:1.6**	**1:1.3:1.4**
	8 " 10	1:0.3:1.0	1:0.[illegible]:1.0	1:0.5:1.0	1:0.5:1.0	1:0.6:0.9
No. 4 to 1 in.	½ to 1	1:1.2:3.1	1:1.3:3.1	1:1.5:3.0	1:1.8:2.9	1:2.1:2.7
	3 " 4	1:0.9:2.7	1:1.1:2.6	1:1.2:2.6	1:1.4:2.5	1:1.7:2.3
	6 " 7	**1:0.6:2.0**	**1:0.7:2.0**	**1:0.8:2.0**	**1:0.9:1.9**	**1:1.1:1.5**
	8 " 10	1:0.3:1.2	1:0.3:1.2	1:0.4:1.2	1:0.5:1.2	1:0.6:1.2
No. 4 to 1½ in.	½ to 1	1:1.1:3.6	1:1.2:3.5	1:1.5:3.5	1:1.7:3.4	1:2.0:3.2
	3 " 4	1:0.9:3.0	1:1.0:2.9	1:1.2:2.9	1:1.4:2.9	1:1.6:2.7
	6 " 7	**1:0.6:2.2**	**1:0.7:2.2**	**1:0.8:2.2**	**1:0.9:2.2**	**1:1.1:2.1**
	8 " 10	1:0.3:1.4	1:0.3:1.3	1:0.4:1.4	1:0.5:1.4	1:0.5:1.3
No. 4 to 2 in.	½ to 1	1:1.0:4.1	1:1.1:4.1	1:1.2:4.1	1:1.4:4.1	1:1.6:4.0
	3 " 4	1:0.8:3.4	1:0.9:3.4	1:1.0:3.5	1:1.1:3.4	1:1.3:3.4
	6 " 7	**1:0.5:2.6**	**1:0.6:2.6**	**1:0.6:2.7**	**1:0.7:2.6**	**1:0.9:2.6**
	8 " 10	1:0.2:1.6	1:0.3:1.6	1:0.3:1.7	1:0.4:1.7	1:0.4:1.7
⅜ to 1 in.	½ to 1	1:1.4:3.1	1:1.5:3.0	1:1.8:2.9	1:2.1:2.8	1:2.4:2.6
	3 " 4	1:1.1:2.6	1:1.3:2.6	1:1.5:2.5	1:1.7:2.4	1:2.0:2.2
	6 " 7	**1:0.8:2.0**	**1:0.8:2.0**	**1:1.0:1.9**	**1:1.1:1.9**	**1:1.3:1.8**
	8 " 10	1:0.4:1.2	1:0.4:1.2	1:0.5:1.2	1:0.6:1.2	1:0.7:1.1
⅜ to 1½ in.	½ to 1	1:1.4:3.5	1:1.5:3.4	1:1.7:3.4	1:2.0:3.3	1:2.3:3.1
	3 " 4	1:1.1:3.0	1:1.2:2.9	1:1.4:2.9	1:1.6:2.8	1:1.9:2.6
	6 " 7	**1:0.8:2.2**	**1:0.8:2.2**	**1:1.0:2.2**	**1:1.1:2.1**	**1:1.3:2.0**
	8 " 10	1:0.4:1.4	1:0.4:1.4	1:0.5:1.4	1:0.6:1.3	1:0.7:1.3
⅜ to 2 in.	½ to 1	1:1.3:4.0	1:1.4:4.0	1:1.6:4.0	1:1.9:3.9	1:2.1:3.8
	3 " 4	1:1.0:3.4	1:1.2:3.4	1:1.3:3.3	1:1.5:3.3	1:1.7:3.2
	6 " 7	**1:0.7:2.6**	**1:0.8:2.5**	**1:0.9:2.6**	**1:1.0:2.6**	**1:1.1:2.5**
	8 " 10	1:0.4:1.6	1:0.4:1.6	1:0.5:1.6	1:0.5:1.6	1:0.6:1.6
¾ to 1½ in.	½ to 1	1:1.6:3.2	1:1.8:3.2	1:2.1:3.2	1:2.4:3.1	1:2.7:2.9
	3 " 4	1:1.3:2.7	1:1.5:2.7	1:1.7:2.7	1:2.0:2.6	1:2.3:2.5
	6 " 7	**1:0.0:2.0**	**1:1.0:2.1**	**1:1.2:2.0**	**1:1.4:2.0**	**1:1.5:1.8**
	8 " 10	1:0.5:1.2	1:0.5:1.3	1:0.6:1.3	1:0.7:1.3	1:0.8:1.2
¾ to 2 in.	½ to 1	1:1.6:3.7	1:1.8:3.7	1:2.0:3.7	1:2.4:3.6	1:2.6:3.5
	3 " 4	1:1.3:3.1	1:1.5:3.1	1:1.6:3.1	1:1.9:3.1	1:2.2:3.0
	6 " 7	**1:0.9:2.4**	**1:1.1:2.4**	**1:1.1:2.4**	**1:1.3:2.4**	**1:1.5:2.3**
	8 " 10	1:0.5:1.5	1:0.5:1.5	1:0.6:1.5	1:0.7:1.5	1:0.8:1.5
¾ to 3 in.	½ to 1	1:1.6:4.2	1:1.8:4.2	1:2.0:4.2	1:2.3:4.1	1:2.6:4.0
	3 " 4	1:1.3:3.5	1:1.5:3.6	1:1.6:3.6	1:1.9:3.6	1:2.1:3.5
	6 " 7	**1:0.9:2.6**	**1:1.0:2.6**	**1:1.1:2.6**	**1:1.3:2.6**	**1:1.4:2.6**
	8 " 10	1:0.5:1.6	1:0.5:1.6	1:0.6:1.7	1:0.7:1.7	1:0.8:1.7

QUANTITIES OF MATERIALS FOR 1 CU. YD. OF 3,000 LB. PER SQ. IN. CONCRETE.

[The volume of cement is expressed in barrels and of aggregates in cubic yards: F = fine aggregate; C = coarse aggregate. Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement 2 per cent.; fine aggregate, 10 per cent.; coarse aggregate, 5 per cent.]

Size of Coarse Aggregate	Slump, in.	0-No. 30 Cement	0-No. 30 Aggregate F.	0-No. 30 Aggregate C.	0-No. 16 Cement	0-No. 16 Aggregate F.	0-No. 16 Aggregate C.	0-No. 8 Cement	0-No. 8 Aggregate F.	0-No. 8 Aggregate C.	0-No. 4 Cement	0-No. 4 Aggregate F.	0-No. 4 Aggregate C.	0-3/8 in. Cement	0-3/8 in. Aggregate F.	0-3/8 in. Aggregate C.
None	½ to 1	3.08	.68		2.96	.74		2.65	.78		2.34	.80		2.14	.86	
	3 " 4	3.61	.64		3.31	.69		2.93	.74		2.66	.75		2.37	.81	
	6 " 7	**3.99**	**.53**		**3.79**	**.56**		**3.57**	**.63**		**3.18**	**.66**		**2.93**	**.69**	
	8 " 10	4.77	.35		4.63	.41		4.34	.45		3.93	.47		3.79	.50	
No. 4 to ¾ in.	½ to 1	1.75	.34	.70	1.73	.38	.66	1.69	.42	.63	1.68	.46	.58	1.59	.54	.49
	3 " 4	2.00	.30	.68	1.97	.35	.64	1.93	.40	.63	1.86	.44	.55	1.86	.52	.49
	6 " 7	**2.48**	**.26**	**.62**	**2.46**	**.29**	**.62**	**2.38**	**.32**	**.60**	**2.37**	**.39**	**.56**	**2.35**	**.45**	**.49**
	8 " 10	3.46	.15	.51	3.44	.20	.51	3.38	.25	.50	3.34	.25	.49	3.31	.29	.44
No. 4 to 1 in.	½ to 1	1.68	.30	.77	1.65	.32	.76	1.60	.36	.71	1.55	.41	.66	1.53	.47	.61
	3 " 4	1.88	.25	.75	1.86	.30	.72	1.83	.32	.70	1.78	.37	.66	1.76	.44	.60
	6 " 7	**2.39**	**.21**	**.71**	**2.38**	**.25**	**.70**	**2.32**	**.27**	**.69**	**2.27**	**.30**	**.64**	**2.26**	**.37**	**.60**
	8 " 10	3.32	.15	.59	3.30	.16	.59	3.25	.19	.58	3.21	.24	.57	3.18	.28	.56
No. 4 to 1½ in.	½ to 1	1.58	.23	.84	1.55	.28	.80	1.50	.33	.78	1.46	.37	.73	1.46	.43	.69
	3 " 4	1.80	.24	.80	1.78	.26	.76	1.73	.31	.74	1.68	.35	.72	1.67	.40	.67
	6 " 7	**2.30**	**.20**	**.75**	**2.27**	**.24**	**.74**	**2.21**	**.20**	**.72**	**2.15**	**.29**	**.70**	**2.12**	**.35**	**.66**
	8 " 10	3.19	.14	.66	3.17	.14	.61	3.09	.18	.64	3.04	.22	.63	3.02	.22	.58
No. 4 to 2 in.	½ to 1	1.50	.22	.91	1.49	.24	.90	1.43	.25	.87	1.38	.29	.84	1.38	.33	.82
	3 " 4	1.73	.20	.87	1.71	.23	.86	1.65	.24	.85	1.60	.26	.81	1.60	.31	.80
	6 " 7	**2.18**	**.16**	**.84**	**2.14**	**.19**	**.82**	**2.06**	**.18**	**.82**	**2.01**	**.21**	**.77**	**2.01**	**.27**	**.77**
	8 " 10	3.12	.09	.74	3.09	.14	.73	3.04	.14	.76	2.94	.17	.74	2.94	.17	.74
⅜ to 1 in.	½ to 1	1.69	.35	.77	1.65	.37	.73	1.60	.43	.69	1.54	.48	.64	1.51	.54	.68
	3 " 4	1.91	.31	.73	1.88	.36	.72	1.82	.40	.67	1.78	.45	.63	1.73	.51	.56
	6 " 7	**2.40**	**.28**	**.71**	**2.36**	**.28**	**.70**	**2.31**	**.34**	**.05**	**2.26**	**.37**	**.64**	**2.19**	**.42**	**.58**
	8 " 10	3.23	.19	.57	3.21	.19	.57	3.15	.23	.56	3.00	.27	.63	2.93	.30	.48
⅜ to 1½ in.	½ to 1	1.57	.32	.81	1.55	.34	.78	1.50	.38	.75	1.45	.43	.71	1.48	.49	.66
	3 " 4	1.81	.30	.81	1.78	.32	.76	1.73	.36	.74	1.68	.40	.70	1.63	.46	.63
	6 " 7	**2.30**	**.20**	**.75**	**2.26**	**.27**	**.74**	**2.20**	**.33**	**.72**	**2.15**	**.35**	**.67**	**2.08**	**.35**	**.62**
	8 " 10	2.97	.18	.61	2.94	.17	.61	2.88	.21	.60	2.87	.26	.60	2.78	.30	.55
⅜ to 2 in.	½ to 1	1.49	.29	.88	1.48	.32	.88	1.42	.34	.84	1.36	.38	.77	1.34	.42	.75
	3 " 4	1.73	.26	.87	1.70	.30	.86	1.63	.31	.80	1.58	.35	.77	1.55	.39	.73
	6 " 7	**2.18**	**.23**	**.84**	**2.12**	**.25**	**.79**	**2.05**	**.27**	**.79**	**2.01**	**.30**	**.77**	**1.93**	**.31**	**.72**
	8 " 10	2.98	.18	.71	2.99	.18	.71	2.90	.21	.69	2.93	.22	.69	2.84	.25	.67
¾ to 1½ in.	½ to 1	1.55	.37	.73	1.52	.40	.72	1.48	.46	.70	1.41	.50	.65	1.38	.56	.59
	3 " 4	1.79	.34	.71	1.75	.39	.70	1.71	.43	.68	1.63	.48	.63	1.59	.54	.59
	6 " 7	**2.29**	**.30**	**.68**	**2.24**	**.33**	**.70**	**2.17**	**.30**	**.64**	**2.08**	**.43**	**.62**	**2.03**	**.45**	**.54**
	8 " 10	3.03	.22	.54	3.01	.22	.58	2.93	.26	.56	2.90	.30	.66	2.88	.34	.51
¾ to 2 in.	½ to 1	1.47	.35	.80	1.44	.38	.79	1.40	.41	.77	1.34	.48	.71	1.29	.60	.67
	3 " 4	1.70	.33	.78	1.66	.37	.76	1.62	.38	.74	1.53	.43	.70	1.50	.49	.67
	6 " 7	**2.16**	**.29**	**.77**	**2.08**	**.34**	**.74**	**2.04**	**.33**	**.73**	**1.92**	**.37**	**.68**	**1.00**	**.42**	**.65**
	8 " 10	2.97	.22	.66	2.97	.22	.66	2.81	.25	.62	2.74	.28	.42	2.74	.23	.42
¾ to 3 in.	½ to 1	1.39	.33	.86	1.35	.36	.84	1.30	.38	.81	1.25	.42	.76	1.21	.46	.71
	3 " 4	1.60	.31	.83	1.55	.34	.83	1.52	.36	.81	1.46	.41	.78	1.42	.44	.73
	6 " 7	**2.03**	**.27**	**.78**	**1.98**	**.20**	**.76**	**1.94**	**.32**	**.75**	**1.87**	**.36**	**.72**	**1.83**	**.38**	**.70**
	8 " 10	2.87	.21	.68	2.85	.21	.67	2.75	.24	.69	2.69	.28	.68	2.64	.31	.66

(See page 745.)

Proportions for 3,500 lb. per sq. in. Concrete.

[Based on 28-day compressive strength of 6 by 12 in. cylinders. Proportions are expressed by volume as follows: Portland cement : fine aggregate : coarse aggregate—Thus 1 : 2·6 : 4·6 indicates 1 part by volume of Portland cement, 2·6 parts by volume of fine aggregate, and 4·6 parts by volume of coarse aggregate.]

Size of Coarse Aggregate	Slump. in.	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ in
None	½ to 1	1:1.2	1:1.4	1:1.6	1:1.9	1:2.2
	3 " 4	1:1.0	1:1.1	1:1.3	1:1.5	1:1.8
	6 " 7	**1:0.6**	**1:0.8**	**1:0.9**	**1:1.0**	**1:1.2**
	8 " 10	1:0.3	1:0.4	1:0.4	1:0.5	1:0.6
No. 4 to ¾ in.	½ to 1	1:1.0:2.2	1:1.1:2.2	1:1.3:2.1	1:1.5:2.0	1:1.8:1.8
	3 " 4	1:0.8:1.9	1:0.9:1.9	1:1.0:1.8	1:1.2:1.7	1:1.4:1.5
	6 " 7	**1:0.5:1.3**	**1:0.6:1.4**	**1:0.6:1.3**	**1:0.8:1.3**	**1:0.9:1.2**
	8 " 10	1:0.2:0.7	1:0.2:0.7	1:0.3:0.7	1:0.3:0.7	1:0.4:0.6
No. 4 to 1 in.	½ to 1	1:0.9:2.5	1:1.0:2.6	1:1.2:2.5	1:1.4:2.4	1:1.6:2.3
	3 " 4	1:0.7:2.2	1:0.8:2.2	1:0.9:2.2	1:1.1:2.1	1:1.3:2.0
	6 " 7	**1:0.4:1.5**	**1:0.5:1.5**	**1:0.6:1.5**	**1:0.6:1.5**	**1:0.8:1.4**
	8 " 10	1:0.2:0.8	1:0.2:0.8	1:0.2:0.8	1:0.3:0.8	1:0.3:0.8
No. 4 to 1½ in.	½ to 1	1:0.9:2.9	1:1.0:2.9	1:1.1:2.9	1:1.3:2.8	1:1.5:2.7
	3 " 4	1:0.7:2.5	1:0.8:2.4	1:0.9:2.4	1:1.0:2.4	1:1.2:2.3
	6 " 7	**1:0.4:1.8**	**1:0.5:1.7**	**1:0.5:1.8**	**1:0.6:1.7**	**1:0.7:1.7**
	8 " 10	1:0.2:0.9	1:0.2:0.9	1:0.2:0.9	1:0.2:0.9	1:0.3:0.9
No. 4 to 2 in.	½ to 1	1:0.7:3.3	1:0.8:3.3	1:0.9:3.4	1:1.0:3.3	1:1.2:3.3
	3 " 4	1:0.6:2.8	1:0.6:2.8	1:0.7:2.8	1:0.8:2.8	1:1.0:2.8
	6 " 7	**1:0.3:2.0**	**1:0.4:2.0**	**1:0.4:2.0**	**1:0.5:2.0**	**1:0.6:2.0**
	8 " 10	1:0.1:1.0	1:0.1:1.0	1:0.2:1.0	1:0.2:1.0	1:0.2:1.0
⅜ to 1 in.	½ to 1	1:1.1:2.5	1:1.2:2.5	1:1.4:2.5	1:1.6:2.3	1:1.8:2.2
	3 " 4	1:0.8:2.1	1:0.9:2.1	1:1.1:2.1	1:1.3:2.0	1:1.5:1.9
	6 " 7	**1:0.5:1.5**	**1:0.6:1.5**	**1:0.7:1.5**	**1:0.8:1.4**	**1:0.9:1.4**
	8 " 10	1:0.2:0.8	1:0.2:0.8	1:0.3:0.8	1:0.3:0.8	1:0.4:0.7
⅜ to 1½ in.	½ to 1	1:1.0:2.8	1:1.2:2.8	1:1.3:2.8	1:1.6:2.7	1:1.8:2.6
	3 " 4	1:0.8:2.4	1:0.9:2.4	1:1.1:2.4	1:1.2:2.3	1:1.5:2.3
	6 " 7	**1:0.5:1.7**	**1:0.6:1.7**	**1:0.7:1.7**	**1:0.8:1.7**	**1:0.9:1.6**
	8 " 10	1:0.2:0.8	1:0.2:0.8	1:0.2:0.8	1:0.3:0.8	1:0.4:0.8
⅜ to 2 in.	½ to 1	1:1.0:3.2	1:1.1:3.2	1:1.2:3.2	1:1.4:3.2	1:1.6:3.1
	3 " 4	1:0.8:2.7	1:0.8:2.7	1:1.0:2.7	1:1.1:2.7	1:1.3:2.7
	6 " 7	**1:0.5:1.9**	**1:0.5:1.9**	**1:0.6:2.0**	**1:0.7:2.0**	**1:0.8:1.9**
	8 " 10	1:0.2:0.9	1:0.2:1.0	1:0.2:1.0	1:0.3:1.0	1:0.3:1.0
¾ to 1½ in.	½ to 1	1:1.3:2.6	1:1.4:2.7	1:1.6:2.6	1:1.9:2.6	1:2.2:2.4
	3 " 4	1:1.0:2.2	1:1.2:2.3	1:1.3:2.2	1:1.5:2.2	1:1.8:2.1
	6 " 7	**1:0.7:1.6**	**1:0.7:1.6**	**1:0.9:1.6**	**1:1.0:1.6**	**1:1.2:1.6**
	8 " 10	1:0.3:0.8	1:0.3:0.8	1:0.4:0.8	1:0.4:0.8	1:0.5:0.8
¾ to 2 in.	½ to 1	1:1.2:3.0	1:1.4:3.1	1:1.6:3.1	1:1.8:3.1	1:2.1:3.0
	3 " 4	1:1.0:2.6	1:1.1:2.6	1:1.2:2.6	1:1.5:2.6	1:1.7:2.5
	6 " 7	**1:0.6:1.8**	**1:0.7:1.8**	**1:0.8:1.9**	**1:0.9:1.9**	**1:1.1:1.9**
	8 " 10	1:0.3:0.9	1:0.3:0.9	1:0.3:0.9	1:0.4:0.9	1:0.5:0.9
¾ to 3 in.	½ to 1	1:1.2:3.4	1:1.3:3.4	1:1.5:3.4	1:1.7:3.3	1:2.0:3.3
	3 " 4	1:1.0:2.8	1:1.1:2.8	1:1.2:2.8	1:1.4:2.8	1:1.6:2.8
	6 " 7	**1:0.6:2.0**	**1:0.7:2.0**	**1:0.8:2.0**	**1:0.9:2.0**	**1:1.0:2.0**
	8 " 10	1:0.3:1.0	1:0.3:1.0	1:0.3:1.0	1:0.4:1.0	1:0.4:1.0

Quantities of Materials for 1 cu. yd. of 3,500 lb. per sq. in. Concrete.

[The volume of cement is expressed in barrels and of aggregates in cubic yards: F = fine aggregate; C = coarse aggregate. Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement, 2 per cent.; fine aggregate, 10 per cent.; coarse aggregate, 5 per cent.]

Size of Coarse Aggregate	Slump. in.	Quantities of Materials Using Fine Aggregate of Different Sizes														
		0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-⅜ in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	3.58	.64		3.38	.70		3.11	.74		2.71	.76		2.48	.81	
	3 " 4	3.90	.58		3.83	.62		3.51	.68		3.13	.70		2.81	.75	
	6 " 7	**4.82**	**.43**		**4.34**	**.52**		**4.12**	**.55**		**3.79**	**.56**		**3.46**	**.61**	
	8 " 10				5.00	.30		4.95	.29		4.48	.33		4.37	.30	
No. 4 to ¾ in.	½ to 1	2.08	.31	.68	2.06	.34	.67	2.01	.39	.63	1.91	.42	.57	1.92	.51	.51
	3 " 4	2.38	.28	.67	2.36	.31	.66	2.52	.37	.67	2.25	.40	.57	2.22	.46	.49
	6 " 7	**3.08**	**.23**	**.59**	**3.02**	**.27**	**.63**	**2.06**	**.26**	**.57**	**2.88**	**.34**	**.56**	**2.83**	**.38**	**.50**
	8 " 10	4.02	.12	.42	3.96	.12	.41	3.89	.17	.40	3.83	.17	.40	3.79	.22	.34
No. 4 to 1 in.	½ to 1	1.95	.26	.75	1.93	.29	.74	1.90	.34	.70	1.84	.38	.65	1.84	.43	.63
	3 " 4	2.27	.24	.74	2.25	.27	.73	2.18	.29	.71	2.15	.35	.67	2.10	.40	.62
	6 " 7	**2.93**	**.17**	**.65**	**2.89**	**.21**	**.64**	**2.79**	**.25**	**.62**	**2.74**	**.24**	**.61**	**2.67**	**.32**	**.55**
	8 " 10	3.88	.11	.46	3.82	.11	.45	3.79	.11	.45	3.68	.16	.44	3.67	.16	.43
No. 4 to 1½ in.	½ to 1	1.85	.25	.79	1.85	.27	.79	1.80	.29	.77	1.70	.33	.70	1.73	.38	.69
	3 " 4	2.14	.22	.79	2.11	.25	.75	2.05	.27	.73	1.97	.29	.70	1.98	.35	.67
	6 " 7	**2.76**	**.22**	**.74**	**2.70**	**.20**	**.68**	**2.59**	**.19**	**.69**	**2.58**	**.23**	**.65**	**2.58**	**.27**	**.65**
	8 " 10	3.79	.11	.50	3.69	.11	.49	3.67	.11	.49	3.72	.11	.50	3.80	.17	.51
No. 4 to 2 in.	½ to 1	1.79	.19	.87	1.77	.21	.86	1.71	.23	.86	1.68	.25	.87	1.65	.29	.81
	3 " 4	2.04	.18	.84	2.00	.18	.83	1.95	.20	.81	1.92	.23	.80	1.91	.28	.79
	6 " 7	**2.02**	**.12**	**.78**	**2.60**	**.15**	**.77**	**2.52**	**.15**	**.75**	**2.50**	**.19**	**.74**	**2.50**	**.22**	**.74**
	8 " 10	3.81	.06	.56	3.75	.06	.56	3.72	.11	.55	3.68	.11	.54	3.76	.11	.56
⅜ to 1 in.	½ to 1	2.02	.33	.75	1.94	.34	.72	1.88	.39	.69	1.85	.44	.63	1.79	.48	.58
	3 " 4	2.28	.27	.71	2.24	.30	.70	2.18	.35	.68	2.14	.41	.63	2.05	.45	.58
	6 " 7	**2.86**	**.21**	**.64**	**2.84**	**.25**	**.63**	**2.76**	**.29**	**.61**	**2.74**	**.32**	**.57**	**2.66**	**.35**	**.55**
	8 " 10	3.88	.11	.46	3.82	.11	.45	3.79	.17	.45	3.68	.16	.44	3.67	.22	.35
⅜ to 1½ in.	½ to 1	1.88	.28	.78	1.85	.33	.77	1.79	.34	.74	1.74	.41	.70	1.69	.45	.65
	3 " 4	2.16	.26	.77	2.10	.28	.75	2.04	.33	.73	1.98	.35	.67	1.93	.43	.66
	6 " 7	**2.72**	**.20**	**.68**	**2.66**	**.24**	**.67**	**2.59**	**.27**	**.65**	**2.56**	**.30**	**.64**	**2.52**	**.34**	**.60**
	8 " 10	3.79	.11	.45	3.69	.11	.44	3.67	.16	.43	3.40	.15	.40	3.31	.20	.39
⅜ to 2 in.	½ to 1	1.78	.26	.84	1.75	.28	.83	1.69	.30	.80	1.63	.36	.77	1.59	.38	.73
	3 " 4	2.03	.24	.81	1.98	.23	.79	1.93	.29	.77	1.91	.31	.76	1.84	.35	.73
	6 " 7	**2.58**	**.19**	**.73**	**2.54**	**.19**	**.71**	**2.49**	**.22**	**.74**	**2.47**	**.26**	**.73**	**2.40**	**.28**	**.68**
	8 " 10	3.80	.11	.51	3.73	.11	.55	3.64	.11	.54	3.63	.16	.54	3.56	.16	.53
¾ to 1½ in.	½ to 1	1.84	.35	.71	1.82	.38	.73	1.77	.42	.68	1.68	.47	.65	1.65	.54	.59
	3 " 4	2.13	.32	.69	2.09	.37	.71	2.02	.39	.66	1.88	.41	.60	1.89	.50	.59
	6 " 7	**2.68**	**.28**	**.64**	**2.63**	**.27**	**.62**	**2.56**	**.34**	**.61**	**2.49**	**.37**	**.59**	**2.45**	**.44**	**.58**
	8 " 10	3.79	.17	.45	3.69	.16	.43	3.67	.22	.43	3.72	.22	.44	3.66	.21	.43
¾ to 2 in.	½ to 1	1.76	.21	.78	1.73	.36	.79	1.67	.40	.77	1.58	.42	.72	1.55	.48	.69
	3 " 4	2.01	.30	.74	1.95	.31	.75	1.92	.34	.74	1.84	.41	.71	1.80	.45	.67
	6 " 7	**2.58**	**.23**	**.69**	**2.54**	**.26**	**.68**	**2.48**	**.29**	**.70**	**2.40**	**.32**	**.68**	**2.35**	**.38**	**.66**
	8 " 10	3.78	.17	.60	3.73	.17	.50	3.63	.16	.48	3.59	.21	.48	3.49	.26	.46
¾ to 3 in.	½ to 1	1.67	.20	.84	1.61	.31	.81	1.57	.35	.79	1.51	.38	.74	1.47	.43	.72
	3 " 4	1.91	.26	.79	1.86	.30	.77	1.93	.34	.80	1.76	.36	.73	1.71	.40	.71
	6 " 7	**2.48**	**.22**	**.74**	**2.43**	**.25**	**.72**	**2.37**	**.28**	**.70**	**2.30**	**.31**	**.68**	**2.25**	**.33**	**.67**
	8 " 10	3.64	.16	.54	3.57	.16	.53	3.52	.16	[illegible]	3.46	.20	.51	3.38	.20	[illegible]

(See page 745.)

Proportions for 4,000 lb. per sq. in. Concrete.

[Based on 28-day compressive strength of 6 by 12 in. cylinders. Proportions are expressed by volume as follows: Portland cement : fine aggregate : coarse aggregate—Thus 1 : 2·6 : 4·6 indicates 1 part by volume of Portland cement, 2·6 parts by volume of fine aggregate, and 4·6 parts by volume of coarse aggregate.]

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-3/8 in.
None	½ to 1	1:0.9	1:1.1	1:1.2	1:1.5	1:1.7
	3 " 4	1:0.7	1:0.9	1:1.0	1:1.2	1:1.4
	6 " 7	1:0.4	1:0.5	1:0.6	1:0.7	1:0.7
	8 " 10	1:0.1	1:0.2	1:0.2	1:0.2	1:0.3
No. 4 to ¾ in.	½ to 1	1:0.8:1.8	1:0.9:1.8	1:1.0:1.8	1:1.2:1.7	1:1.4:1.5
	3 " 4	1:0.6:1.5	1:0.6:1.4	1:0.8:1.5	1:0.9:1.4	1:1.1:1.3
	6 " 7	1:0.3:0.9	1:0.4:1.0	1:0.4:0.9	1:0.5:0.9	1:0.6:0.9
	8 " 10	1:0.1:0.3	1:0.1:0.3	1:0.1:0.3	1:0.1:0.3	1:0.2:0.3
No. 4 to 1 in.	½ to 1	1:0.7:2.1	1:0.8:2.1	1:0.9:2.1	1:1.0:2.0	1:1.2:1.9
	3 " 4	1:0.5:1.7	1:0.6:1.6	1:0.7:1.7	1:0.8:1.7	1:0.9:1.6
	6 " 7	1:0.3:1.1	1:0.3:1.1	1:0.4:1.1	1:0.4:1.1	1:0.5:1.1
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4
No. 4 to 1½ in.	½ to 1	1:0.6:2.4	1:0.7:2.4	1:0.8:2.4	1:1.0:2.3	1:1.1:2.2
	3 " 4	1:0.5:2.0	1:0.5:1.9	1:0.6:2.0	1:0.7:1.9	1:0.9:1.9
	6 " 7	1:0.3:1.2	1:0.3:1.2	1:0.3:1.2	1:0.4:1.2	1:0.4:1.2
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4
No. 4 to 2 in.	½ to 1	1:0.5:2.7	1:0.6:2.7	1:0.7:2.7	1:0.8:2.7	1:0.9:2.8
	3 " 4	1:0.4:2.2	1:0.4:2.2	1:0.5:2.3	1:0.6:2.3	1:0.7:2.3
	6 " 7	1:0.2:1.4	1:0.2:1.4	1:0.3:1.4	1:0.3:1.5	1:0.3:1.4
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.5	1:0.1:0.5	1:0.1:0.5
⅜ to 1 in.	½ to 1	1:0.8:2.1	1:0.9:2.0	1:1.0:2.0	1:1.2:1.9	1:1.4:1.8
	3 " 4	1:0.6:1.7	1:0.7:1.7	1:0.8:1.6	1:0.9:1.6	1:1.1:1.5
	6 " 7	1:0.3:1.1	1:0.4:1.1	1:0.4:1.0	1:0.5:1.0	1:0.6:1.0
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.2:0.4
⅜ to 1½ in.	½ to 1	1:0.8:2.3	1:0.9:2.3	1:1.0:2.3	1:1.2:2.3	1:1.4:2.2
	3 " 4	1:0.6:1.9	1:0.7:1.9	1:0.8:1.9	1:0.9:1.9	1:1.1:1.8
	6 " 7	1:0.3:1.2	1:0.4:1.2	1:0.4:1.2	1:0.5:1.2	1:0.6:1.2
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.2:0.4
⅜ to 2 in.	½ to 1	1:0.7:2.6	1:0.8:2.6	1:0.9:2.6	1:1.0:2.6	1:1.2:2.6
	3 " 4	1:0.6:2.1	1:0.6:2.2	1:0.7:2.2	1:0.8:2.2	1:1.0:2.2
	6 " 7	1:0.3:1.4	1:0.3:1.4	1:0.4:1.4	1:0.4:1.4	1:0.5:1.4
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.5	1:0.1:0.4	1:0.1:0.5
¾ to 1½ in.	½ to 1	1:1.0:2.2	1:1.1:2.2	1:1.3:2.2	1:1.5:2.1	1:1.7:2.0
	3 " 4	1:0.8:1.8	1:0.9:1.8	1:1.0:1.8	1:1.2:1.8	1:1.3:1.7
	6 " 7	1:0.4:1.1	1:0.5:1.1	1:0.6:1.2	1:0.7:1.1	1:0.8:1.1
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.2:0.4	1:0.2:0.4	1:0.2:0.4
¾ to 2 in.	½ to 1	1:0.9:2.5	1:1.0:2.5	1:1.2:2.5	1:1.4:2.5	1:1.6:2.5
	3 " 4	1:0.7:2.0	1:0.8:2.1	1:0.9:2.1	1:1.1:2.1	1:1.3:2.1
	6 " 7	1:0.4:1.3	1:0.5:1.3	1:0.5:1.4	1:0.6:1.4	1:0.7:1.3
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.2:0.4	1:0.2:0.4	1:0.2:0.4
¾ to 3 in.	½ to 1	1:0.9:2.7	1:1.0:2.7	1:1.2:2.8	1:1.3:2.7	1:1.5:2.7
	3 " 4	1:0.7:2.2	1:0.8:2.2	1:0.9:2.3	1:1.0:2.3	1:1.2:2.2
	6 " 7	1:0.4:1.4	1:0.4:1.4	1:0.5:1.5	1:0.6:1.5	1:0.7:1.5
	8 " 10	1:0.1:0.5	1:0.1:0.5	1:0.1:0.5	1:0.2:0.5	1:0.2:0.5

Quantities of Materials for 1 cu. yd. of 4,000 lb. per sq. in. Concrete.

[The volume of cement is expressed in barrels and of aggregates in cubic yards: F = fine aggregate; C = coarse aggregate. Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement, 2 per cent.; fine aggregate, 10 per cent.; coarse aggregate, 5 per cent.]

Size of Coarse Aggregate	Slump, in.	Quantities of Materials Using Fine Aggregate of Different Sizes														
		0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-⅜ in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	4.21	.56		3.91	.65		3.75	.79		3.19	.71		2.96	.75	
	3 " 4	4.64	.48		4.25	.57		4.03	.60		3.57	.64		3.27	.68	
	6 " 7	5.05	.30		5.21	.39		4.89	.44		4.36	.45		4.41	.46	
	8 " 10													4.78	.21	
No. 4 to ¾ in.	½ to 1	2.46	.29	.65	2.44	.32	.65	2.39	.35	.64	2.33	.41	.59	2.30	.48	.51
	3 " 4	2.86	.25	.64	2.80	.25	.58	[illegible].74	.32	.61	2.64	.35	.55	2.61	.42	.50
	6 " 7	3.68	.16	.49	3.67	.22	.54	3.62	.21	.48	3.56	.26	.48	3.54	.23	.34
	8 " 10	4.79	.06	.23	4.79	.07	.23	4.77	.08	.23	4.76	.10	.23	4.74	.11	.22
No. 4 to 1 in.	½ to 1	2.36	.24	.73	2.32	.27	.72	2.27	.30	.71	2.21	.33	.65	2.18	.39	.61
	3 " 4	2.71	.20	.68	2.65	.24	.63	2.58	.27	.65	2.56	.30	.64	2.54	.34	.60
	6 " 7	3.59	.16	.58	3.58	.16	.58	3.51	.21	.57	3.46	.20	.56	3.48	.26	.57
	8 " 10	4.79	.05	.25	4.76	.05	.26	4.73	.07	.26	4.70	.08	.26	4.69	.09	.26
No. 4 to 1½ in.	½ to 1	2.25	.20	.80	2.21	.23	.78	2.15	.25	.76	2.03	.30	.69	2.05	.33	.67
	3 " 4	2.56	.19	.76	2.64	.19	.71	2.46	.22	.73	2.43	.25	.68	2.42	.32	.68
	6 " 7	3.48	.15	.62	3.47	.15	.62	3.30	.15	.60	3.34	.20	.59	3.34	.20	.59
	8 " 10	4.69	.04	.28	4.69	.05	.28	4.69	.06	.29	4.67	.07	.29	4.67	.08	.29
No. 4 to 2 in.	½ to 1	2.14	.16	.86	2.10	.19	.84	2.03	.21	.81	2.00	.24	.80	1.91	.26	.79
	3 " 4	2.47	.15	.80	2.45	.15	.80	2.37	.18	.81	2.33	.21	.79	2.31	.24	.78
	6 " 7	3.36	.10	.70	3.33	.10	.69	3.24	.14	.67	3.19	.14	.71	3.20	.14	.66
	8 " 10	4.69	.03	.31	4.68	.03	.30	4.67	.04	.32	4.61	.04	.33	4.54	.05	.33
⅜ to 1 in.	½ to 1	2.36	.29	.73	2.32	.31	.69	2.26	.33	.67	2.22	.39	.62	2.13	.44	.57
	3 " 4	2.65	.24	.67	2.62	.27	.66	2.58	.31	.61	2.54	.34	.60	2.48	.40	.55
	6 " 7	3.42	.15	.56	3.39	.20	.55	3.33	.20	.49	3.30	.24	.49	3.23	.29	.48
	8 " 10	4.79	.06	.26	4.76	.07	.25	4.73	.08	.26	4.70	.10	.25	4.69	.12	.24
⅜ to 1½ in.	½ to 1	2.26	.27	.77	2.20	.29	.75	2.14	.32	.73	2.08	.37	.71	2.00	.41	.65
	3 " 4	2.54	.23	.71	2.51	.26	.71	2.48	.29	.70	2.42	.32	.68	2.36	.38	.63
	6 " 7	3.24	.14	.58	3.17	.19	.56	3.16	.19	.56	3.10	.23	.55	3.13	.28	.56
	8 " 10	4.69	.06	.28	4.69	.07	.28	4.69	.08	.28	4.67	.09	.28	4.67	.11	.28
⅜ to 2 in.	½ to 1	2.14	.22	.82	2.08	.25	.80	2.01	.27	.77	1.98	.29	.76	1.92	.34	.74
	3 " 4	2.46	.22	.76	2.42	.21	.79	2.34	.24	.76	2.31	.27	.75	2.22	.33	.72
	6 " 7	3.14	.14	.65	3.07	.14	.64	3.02	.18	.63	3.02	.18	.63	2.98	.22	.62
	8 " 10	4.69	.05	.30	4.68	.06	.30	4.67	.07	.32	4.61	.08	.31	4.54	.08	.31
¾ to 1½ in.	½ to 1	2.23	.33	.72	2.18	.35	.71	2.12	.41	.69	2.01	.45	.62	1.95	.49	.53
	3 " 4	2.53	.30	.68	2.49	.33	.66	2.44	.36	.65	2.42	.43	.65	2.29	.44	.58
	6 " 7	3.18	.19	.52	3.12	.23	.51	3.03	.27	.54	2.97	.31	.48	2.98	.35	.49
	8 " 10	4.69	.08	.26	4.69	.10	.27	4.69	.11	.28	4.67	.12	.28	4.67	.15	.27
¾ to 2 in.	½ to 1	2.11	.28	.78	2.05	.30	.76	1.99	.35	.74	1.91	.40	.71	1.88	.44	.69
	3 " 4	2.44	.25	.72	2.39	.28	.74	2.34	.31	.73	2.24	.36	.70	2.18	.42	.68
	6 " 7	3.12	.18	.60	3.11	.23	.60	3.00	.22	.62	2.94	.26	.61	2.90	.30	.56
	8 " 10	4.69	.08	.29	4.68	.09	.30	4.67	.10	.30	4.61	.11	.30	4.54	.13	.30
¾ to 3 in.	½ to 1	1.98	.25	.79	1.94	.29	.77	1.90	.34	.79	1.84	.35	.74	1.78	.40	.71
	3 " 4	2.33	.24	.76	2.28	.27	.78	2.21	.30	.75	2.12	.31	.72	2.06	.37	.67
	6 " 7	3.00	.18	.62	2.97	.18	.62	2.96	.22	.66	2.90	.26	.64	2.77	.29	.62
	8 " 10	4.60	.08	.32	4.54	.08	.32	4.49	.09	.32	4.44	.10	.32	4.43	.12	.32

(See page 745.)

CORRESPONDENCE.

"THE RESISTANCE TO FIRE OF CONCRETE AND REINFORCED CONCRETE."

Sir,—Under this title a paper has recently been read before the British Association by Professor F. C. Lea and Mr. R. E. Stradling. Any one reading some of the reports of this paper would gather the impression that reinforced concrete was of absolutely no use as a fire resisting material. In our opinion the manner in which these two authors deal with the subject is extremely detrimental to the use of concrete and reinforced concrete, and we must ask you to do everything you can in your power to point out the following :—

(1) No one designing or constructing reinforced concrete ever claims that this material is absolutely fireproof or absolutely fire resisting, but simply that it is the most fire resisting material which can be used for constructional purposes.

(2) In many cases it has been proved that buildings or structures subjected to fire have resisted where everything else has failed.

(3) The British Fire Prevention Committee has carried out extensive tests on large floors in the presence of a number of architects, engineers, and other people interested in the matter, and these results have in every case proved that concrete and reinforced concrete was certainly much more fire resisting than either timber, steel, or even brickwork.

It is unfortunately impossible for us to call upon the Concrete Institute to take up the cudgels in defence of reinforced concrete in a case like this, as the Institute would probably consider that it was being called upon to take sides in a trade dispute. We, however, who have spent a very considerable amount of money in carrying out experiments under the British Fire Prevention Committee with the best possible results, and with the knowledge we have of the considerable fire resistance of reinforced concrete, cannot allow disparaging statements to be made on the fire resistance of reinforced concrete by professors who appear to disdain the important work carried out by the British Fire Prevention Committee as being purely empirical and of no value.

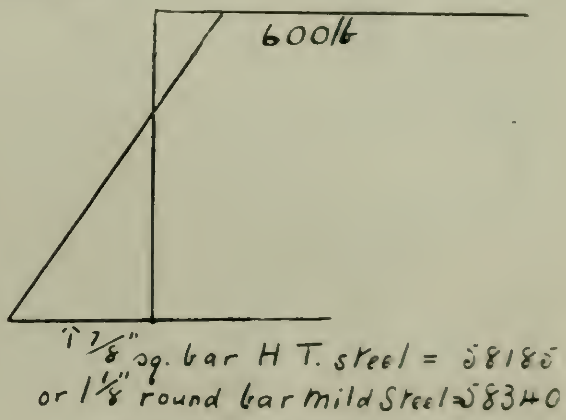
G. C. Workman, *Man. Director.*
Edmond Coignet, Ltd.

[*** This matter is also referred to in our Editorial pages.]

MILD VERSUS HIGH-TENSILE STEEL.

Sir,—It is evident that neither Mr. Workman nor Dr. Faber understands properly the contention I put forward, because they are both thinking mathematically and losing sight of the fact that although the smaller diameter high-tensile steel bar may be stressed higher per sq. in. than the larger diameter mild steel (low-tensile) bar, the actual safe working stress in each bar is practically the same ; the safe working stress to the yield point (which is the limit of resistance for reinforced concrete) is much higher in the high-tensile bar as will be seen by the following illustration.

	Area.	Yield Pt. per sq. in.	Ultimate Tensile per sq. in.	Actual yield of section.	Ultimate strength of section.
⅞" sq. Tensile bar	·7656	60,000	76,000	45,936	5[illegible],1[illegible]5
1⅛" M.S. Round bar	·9940	35,000	60,000	34,790	[illegible]



2·603 lbs. per ft. = ⅞ in. H.T. sq. bar.
4·303 lbs. per ft. = 1⅛ in. M.S. round bar.

The above figures—58,185 lb. and 58,340 lb.—are the tensile stresses of each section; the safe working stress would be one-fourth of these figures.

Theory and mathematics lacking practice may often trap themselves and confuse issues, and I think this is a case where the theoretical and mathematical mind is grasping the shadow and losing the substance of my contention. I thank you for publishing my letters in your valuable journal, and trust the point raised by me will help to break down an erroneous idea.

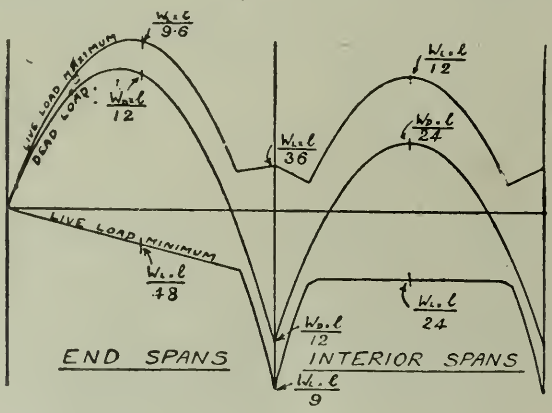
Arthur W. C. Shelf.
Engineers' Club,
London, W.

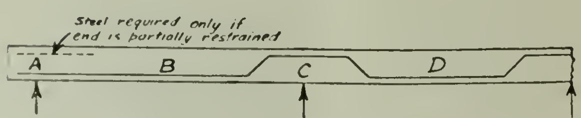
QUESTIONS AND ANSWERS RELATING TO CONCRETE.

Readers are cordially invited to send in questions relating to concrete. These questions will be replied to by an expert, and, as far as possible, answered at once direct and subsequently published where they are of sufficient general interest. Readers should supply full name and address, but only initials will be published. Stamped envelopes should be sent for replies.—ED.

BENDING MOMENTS IN CONTINUOUS SLABS.

QUESTION.—I should be much obliged if you could give me some definite information on the following theoretical points, in due course, in the "Questions and Answers" section of your Journal. After reading the books of Dr. Faber and other modern authors, I conclude that the bending moments on a continuous slab or beam can be represented with reasonable accuracy as in the sketch.





Considering a singly-reinforced slab as shown, the sections necessary to be considered for design are marked B, C, D. The same areas of steel (·675 per cent.) and concrete are to be used throughout. Assume $t = 16{,}000$, $c = 600$, $t_c = 60$.

Considering those moments which put the steel in tension, the diagram shows c to have the largest moment, necessitating a depth of slab given by:

$$(w_l.b.l)\,\frac{l}{9} + (w_d.b.l)\,\frac{l}{12} = 95bd^2$$

whence the safe live load per sq. in. is

$$w_l = 855\left(\frac{d}{l}\right)^2 - \tfrac{3}{4}w_d \qquad (1)$$

Now, taking the moments which tend to put the steel in compression, D is seen to be the critical section. Neglecting the compressive resistance due to the steel, the R.M. is $(\frac{1}{2}.60)(b.\frac{1}{2}d_l)(\frac{2}{3}d_l) = 10bdt^2$. So we require a total depth as given by:

$$(w_l.b.l)\,\frac{l}{24} - (w_d.b.l)\,\frac{l}{24} = 10bd_t^2$$

whence the safe live load per sq. in. is

$$w_l = 240\left(\frac{d_t}{l}\right)^2 + w_d \qquad (2)$$

We must take the smaller of the two values given by (1) and (2); the former applies when $w_l =$ about $2w_d$, and the latter when $w_l =$ about $2w_d$.

Thus it would appear that:

(*a*) the section required for interior spans is very slightly *greater* than that required for end spans;

(*b*) for fairly heavy loads (when the live load is greater than about twice the dead load) the slab will fail as a non-reinforced concrete beam.

Yet Dr. Faber seems to consider it safe to design for a B.M. of $(w_l \times w_d)\,\frac{b.l^2}{12}$ for interior spans, and *add* 20 per cent. more steel for end spans, which disagrees with both my conclusions, and gives very different results.

Thus, the slab he gives on p. 117 of the February issue has $d = 4\frac{1}{4}$ in., $d_t = 5$ in., $l = 100$ in., and is said to bear a safe total load of 300 lb. per sq. ft.; as the dead load is 62 lb. per sq. ft. this means that the safe live load is 238 lb. per sq. ft. Calculated by equation (2), however, the safe live load is only 149 lb. per sq. ft., so that the "approximate" method overstates the result by 60 per cent. Is this considered sufficiently accurate? To me it seems both hopelessly inaccurate as regards the final result and also to disregard the very straining action which determines its strength.—B. P. W.

ANSWER.—The equation (1) correctly gives the maximum negative moment at the support, and the equation (2) the negative moment at midspan which can occur if the panel under consideration is unloaded and the two adjacent ones are fully loaded.

The writer quite logically proceeds to design his slab on the basis of $R = 10bd^2$ for this moment, since the slab in his diagram is unreinforced in tension to resist this negative moment at midspan. On this basis he discovers that the interior bay has to be slightly deeper than the exterior bay.

In practice it is found, however, that this treatment leads to uneconomical results and gives results much heavier than are found in practice to be perfectly safe. The question was investigated in "Reinforced Concrete Design," Vol. I, p. 190, and a method of treatment suggested. This problem only arises in cases when the live load exceeds twice the dead load. I have myself in such cases frequently used tension rods at the top of the slab to take up this moment in a definite manner. In any case, the arrangement of steel shown on the diagram is not a happy one, but perhaps it was meant to be roughly diagrammatic only.

As regards the last part of the question, it is always open to a reader to criticise an approximate solution on the score that it is not accurate. The writer will find in "Reinforced Concrete Design," Vols. I and II, sufficient evidence that in taking a simple solution I was doing so deliberately and not in ignorance. If he will refer to the bottom of page 120 in your February issue (to which he refers) he will find the following footnote (referring to the question of moments): "In these articles, only approximate values are used. For accurate values see 'Reinforced Concrete Design,' Vol. II." I had set myself out deliberately in "Reinforced Concrete Simply Explained," to write a *simple* treatise, in *simple* language, and to keep complicated formulæ out of it, because although exact calculations have their importance I considered it desirable to try to present the fundamental principles in as non-mathematical a form as possible.

As a matter of fact, the results are by no means as inaccurate as the writer suggests. Though his formula (1) gives a support moment exceeding $-\frac{wl}{12}$, it occurs only on the centre line. By the time the width of the support is allowed for (the secondary beams plus slab haunches in this case) the moment comes down to $\frac{wl}{12}$.

As regards midspan, $\frac{wl}{12}$ is slightly in excess of the actual moment; but you cannot couple simplicity of treatment and an exact solution.

As regards the possible negative moment at midspan this should not be treated as the writer suggests. The values given on the moment diagram assume all the supports freely pivoted without restraint. In the example in the February issue, the resistance to twisting of the secondary beams would be quite considerable and this negative moment would be much less than given.

In those cases where it requires guarding against, it is far better to use a little top reinforcement (very little suffices as a rule) rather than increase the slab thickness.—O. F.

COMPOSITION JOINTLESS FLOORING.

QUESTION.—I should be glad if you would supply a formula for the manufacture of composition flooring material applicable to wooden or concrete floors. Please state thickness.—J. B.

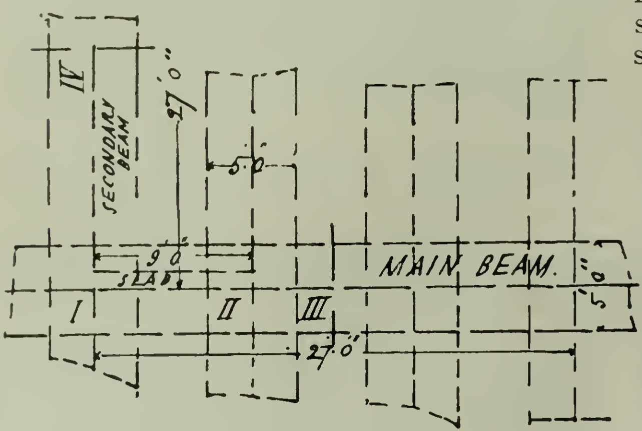
ANSWER.—The following formula gives the proportions in dry bulk of a jointless composition flooring with a basis of wood fibre or flour: Magnesite, 1; wood fibre, $1\frac{1}{2}$; chalk, $\frac{1}{8}$; asbestos, $\frac{1}{4}$. This is amalgamated with a 23 per cent. solution of chloride of magnesium measured with a Baumé hydrometer to the consistency of thick paste, with about equal parts of the formula mixture and the solution. About 10 per cent. of an earth colour should be added to tint the flooring, and red gives the best effect. The flooring can be laid either on concrete or boarding, but if on the latter small nails should be driven in the floor boards projecting about $\frac{1}{4}$ in. at about 9 in. centres to form a key. The flooring is laid in one layer about $\frac{1}{2}$ in. to $\frac{3}{4}$ in. thick as desired in a mastic state, well pressed down and floated to a smooth even surface. It should be allowed about 3 to 7 days to dry and then rubbed down and polished.

Another formula for a composition flooring, to be laid on concrete only, is as follows. Materials required for one super yard: 2 lb. of sawdust, 5 lb. stonedust, 3 lb. Portland cement, $1\frac{1}{2}$ lb. whiting, $\frac{3}{4}$ lb. red oxide, $2\frac{1}{2}$ pints of linseed oil. This is applied $\frac{3}{4}$ in. thick and tamped down to $\frac{1}{4}$ in.

FLOOR DESIGN.

QUESTION.—I should be grateful for your opinion on the following points regarding the method of practical design worked out in detail in Mr. R. J. Harrington-Hudson's excellent *Practical Handbook on Reinforced Concrete.*

(*a*) It seems scarcely legitimate to design a floor system of Tee-beams, the flanges of which constitute the slab system.



CASE	SECTION	EDGE OF FLANGE OR SLAB.	MAX. COMPRESSIVE STRESS IN CONCRETE.			
			SLAB	SEC.RY BEAM	MAIN BEAM	TOTAL
I	MAIN BEAM SUPPORT	TOP BOTTOM	nil. 600	nil. nil.	nil. nil.	nil. 600
II	MAIN BEAM THIRD POINT	TOP BOTTOM	nil. 600	nil. nil.	600 325	600 925
III	MAIN BEAM MID · POINT	TOP BOTTOM	600 nil.	— —	500 200	1,100 200
IV	SECOND.RY BEAM MID-POINT	TOP BOTTOM	nil. 600	600 78	— —	600 678

Hence, owing to the circumstance of the Θ support moments in the main and secondary beams being in excess of their respective resistance moments, and the consequent introduction of steel in both flanges, the concrete has only been stressed as a *slab* in Case I.

In Cases II and III, excessive stresses are induced.

In Case IV, stresses in planes perpendicular to each other.

(*b*) Is it not desirable to design members so that their neutral axes meet in a common intersection point at each joint in a monolithic structure?—H. C. K.

ANSWER.—Our correspondent brings out well the point that slab stresses due to slab bending increase the slab stresses due to main beam bending. But in our view the remedy is not that suggested in (*b*) in the question, which would add enormously to the complication of reinforced concrete design without apparently reducing the stresses. We would rather suggest (1) curtailment of the width of slab considered as acting as compression member of the main beam, coupled with (2) the adoption of lower stresses.

(1) is effective, because there is no slab bending producing stresses in the direction of the main beam in its immediate vicinity, and probably it would be quite safe to limit the slab width to say the distance between secondary beams.

(2) is an obvious cure and needs no comment.

The point raised by the question is another of the uses of a reasonable factor of safety.

BOOKS ON REINFORCED CONCRETE.

QUESTION.—I should be obliged if you would give me a list of three or four of the best, most recent, and up-to-date text-books on reinforced concrete design and construction. Those which deal with the subject under the following heads are most desired: (*a*) Simple design; (*b*) monolithic design; (*c*) use of diagrams; (*d*) construction, including methods of centering and falsework. What I particularly require is a book which shows how the theory of design and use of diagrams are applied practically, as in a reinforced concrete specialist's office.—C. H.

ANSWER.—Perhaps the following might be helpful :

(*a*) Simple Design—Faber's "Reinforced Concrete Simply Explained" [Oxford Technical Publications].

(*b*) Monolithic Design and Use of Diagrams—Harrington-Hudson's "Reinforced Concrete" [Chapman and Hall]; Faber's "Reinforced Concrete Design," Vols. I and II [Edward Arnold]; "Principles of Reinforced Concrete Construction," Turneaure and Maurer [John Wiley and Sons]; Taylor and Thompson's "Concrete Plain and Reinforced." The last two are American publications. Most of the books also contain chapters on practical construction.

CONCRETE FOR FOUNDATIONS.

QUESTION.—I have a contract in the quantities for which it is stated that the concrete for the foundations, etc., is to be composed of one part cement, one part sand, and six parts broken brick aggregate to pass $1\frac{1}{2}$ in. mesh. I consider that the concrete if mixed in this proportion would not be a solid mass but have a large proportion of voids, and that more sand would be required.—D. P.

ANSWER.—Unless the broken brick contains some fine material the proportions mentioned would certainly give a porous concrete. In that event, two parts of sand to five parts of aggregate would probably give better results.

BOOK REVIEW.

The Stability of Masts and Walls. By Dr.-Ing. H. Döor.

(56 pp.; 41 illustrations. Berlin: Wilhelm Ernst and Sohn. Price 117 marks.)

The author, having been called upon to investigate a particular case, found that the formulæ commonly in use for calculating the stability of masts and walls are not as reliable as they should be. He therefore investigated the subject *de novo*, and has calculated new formulæ for the following :—

(1) A simple mast with its lower end in the ground, the mast being subjected to pressure in a single horizontal direction.

(2) A similar mast with an enlargement just below ground-level but at some distance above the base.

(3) The effect of a turning movement on walls.

(4) A mast with a support on the surface of the ground.

(5) A mast with a support above ground-level.

(6) A wall supported on one side only below ground-level.

(7) A loaded pile.

(8) Foundations subjected to an upward pull.

The results of a large number of experiments made in order to obtain the necessary data are recorded. They showed that there are only two essential factors relating to the portion below ground-level—the diameter of the mast (or the thickness of the wall), and its depth. In a review of a book of this kind it would obviously be unfair to disclose the various formulæ, but so far as the reviewer has been able to check them they appear to be well founded and to follow clearly from the experimental data. The book is in the German language, which is a serious hindrance to its use by English builders and engineers, but to those who can use it the book will be valuable.

MEMORANDA.

Organic Matter in Concrete.

SANDS unsuitable for concrete on account of the presence of loam or other organic matter are to be investigated by the U.S. Bureau of Public Roads, and it is hoped that methods of treatment which will make such sands safe for use will be found.

Proposed Large Concrete Building.

IT is reported that plans have been prepared by a German engineer for the construction of an unusually high reinforced concrete building for use in connection with the fairs held from time to time at Leipzig. The structure will be 410 ft. high and of circular form, with a central well, 200 ft. in diameter, around which accommodation will be provided for exhibits, the building comprising thirty stories in all.

Concrete Roads in New York.

THE progress of concrete roads in New York State is indicated by the fact that there is now the equivalent of two thousand miles of concrete roads 18 ft. wide in that State, and it is interesting to note the statement in an American commercial contemporary that this improvement of the roads "has developed traffic to a point far beyond the imagination of the early road builders."

Strength of Concrete Stoppings.

FOR the purpose of determining specifications for the construction of concrete stoppings in coal mines that may be developed on the public lands of the United States, the Bureau of Mines, in co-operation with the Bureau of Standards, is constructing in the experimental mine at Bruceton, Pa., a chamber in which it is proposed to conduct tests to determine the strength of reinforced concrete stoppings when subjected to a pressure, up to 50 lb. per sq. in., suddenly applied.

Concrete Pit Shaft Lining.

A NEW shaft now being sunk by the Holly Bank Colliery Co. at Hilton, near Cannock Chase, is being lined with concrete 18 in. thick. The shaft will be sunk to a depth of 1,890 ft., of which 540 ft. has so far been reached.

New Concrete Warehouse for Manchester.

MESSRS. RICHARD JOHNSON, CLAPHAM & MORRIS, Ltd., have decided, in order to bring all their warehouse accommodation in Manchester under one roof, with its own sidings, motor garages and road access, to erect a special building giving all these

AEROPLANE VERSUS CONCRETE.

This photograph illustrates a curious accident which recently happened in Belgium. The aeroplane crashed on to one of the military hutments built with concrete blocks made with "Winget" machines. The machine was smashed and the pilot injured, but the building, apart from the roof, withstood the shock without a trace of damage.

requirements. A site has been acquired in Third Avenue, Trafford Park, amounting to over 9,000 square yards. A subsidiary company, Messrs. Johnson's Reinforced Concrete Engineering Co., Ltd.—in conjunction with Mr. Arthur Clayton, M.S.A., architect, of Manchester—have prepared the plans, elevations, etc., and all the engineering work is to be done by the subsidiary company. Work on the site has just commenced, the contract having been let to Messrs. J. Byrom, Ltd., of Bury, and it is anticipated that the building will be in full occupation within a year of this time. The Lever Street premises, of course, will be continued as Head Offices, Show Rooms, etc. Experience has shown the desirability of dealing with the great bulk of goods on the ground floor, with only a first story for some of the lighter goods, and in the new building the first story is formed by galleries cantilevered from the roof columns with special arrangements for connection across the various bays.

Power Station at Shanghai.

The Shanghai Municipal Electricity undertaking has made considerable progress in the last twenty years. It came closely to the sales of Manchester (the largest municipal undertaking in Great Britain) last year. It is expected confidently that the demand will increase rapidly, and to meet the call great extensions at the Riverside Power House are being carried out in reinforced concrete. The work did not progress as rapidly as was hoped in the past year owing to labour shortage. The constructional work is being carried out by Chinese contractors, and the capital outlay on buildings at the Riverside Power House during 1921 was 1,940,334.84 taels.

PROSPECTIVE NEW CONCRETE WORK.

ALLOA.—*Bridge.*—The C.C. has approved a scheme for the construction of a bridge over the river Forth at Alloa (Stirlingshire), at an estimated cost of £171,000.

BARMOUTH.—*Sea Wall.*—The U.D.C. is submitting to the Greener Trustees a scheme for the construction of a sea wall promenade.

BARROW-IN-FURNESS.—*Swimming Pool.*—The Borough Surveyor has been instructed to prepare plans for a swimming pool on the west shore of Walney Island.

BELFAST.—*Harbour Works.*—The Harbour Board proposes to carry out harbour improvements involving an expenditure of £33,000.

BELFAST.—*Road.*—The T.C. proposes to construct a circular road from Chichester Park, via Ballywillin and Ballygomartin Road to Balmoral.

BRIDLINGTON.—*Sea Wall.*—The T.C. is considering a scheme for the construction of a sea wall extending from the Spa to the borough boundary.

BURTON-ON-TRENT.—*Bridge.*—The Corporation is discussing a scheme for the proposed widening of Trent Bridge at Burton, at an estimated cost of £70,000.

COLNE.—*Sewage Works.*—The Corporation has received sanction to borrow £24,000 in connection with a sewage works extension scheme.

EASTBOURNE.—*Sea Wall.*—The Highways Committee has been recommended to carry out an extension of the sea wall, at an estimated cost of £6,680.

EDINBURGH.—*Road.*—The Ministry of Transport has approved a scheme of the T.C. to construct a road of over two miles in length, from Granton to Cramond, at an estimated cost of £70,000.

GLASGOW.—*Boating Pond.*—The Corporation has been advised to proceed with the construction of a boating pond in Rouken Glen Park. The cost is estimated at £10,500.

GLASGOW.—*Bridge.*—The Glasgow Corporation Master of Works has been instructed to invite designs and estimates for the erection of a ferro-concrete bridge across the river Clyde at Oswald Street.

GOSPORT.—*Concrete Work.*—The U.D.C. has been recommended to build a concrete swimming bath, 330 ft. by 60 ft., at an estimated cost of £5,720; and to construct a concrete footbridge across the Moat at Stokes Bay at an estimated cost of £520.

GREENOCK.—*Road.*—The Corporation has decided to proceed with a scheme for the formation of a new highway from Kilmacolm Road to the Inverkip Road. The estimated total cost is between £50,000 and £60,000.

IFLEY.—*New Lock.*—The Works Navigation Committee of the Thames Conservancy has given authority for a new lock 155 ft long, 21 ft. 4 in. wide, and 7 ft. 6 in. deep, to be built in reinforced concrete at an estimated cost of £10,000.

ILFORD.—*Sewage Work.*—The U.D.C. has prepared schemes for submission to the Unemployed Grants Committee, amongst which is the construction of a sewage effluent pipe from Ilford to the Thames, at an estimated cost of £60,000.

IRLAM.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £12,500 for the extension of the sewage disposal works.

LLANHARAN.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Cowbridge R.D.C. for sanction to borrow £22,000 for sewerage and sewage disposal works.

London (Bermondsey).—*Baths.*—The Ministry of Health has held an inquiry into an application by the B.C. for sanction to borrow £160,300 for providing public baths and wash-houses.

Lowestoft.—*Sea Wall.*—The T.C. has given instructions to the Borough Engineer to proceed with the reconstruction of the sea wall and esplanade between Claremont Pier and the concrete wall in front of Rectory Road.

Macclesfield.—*Sewage Works.*—The Corporation proposes spending £17,000 on improving the sewage works.

Middlesbrough.—*Road.*—The Middlesbrough Corporation has decided to make a start with its portion of the new main road between Middlesbrough and Redcar. The estimated cost is £60,000.

Newark.—*Sewage Works.*—The T.C. has received the sanction of the Ministry of Health to a loan of £30,000 for sewage disposal works and sewers.

Peterborough.—*Swimming Bath.*—The Corporation is considering the construction of a reinforced concrete swimming pool, 100 ft. by 40 ft., at an estimated cost of £15,000.

Portknockie.—*Reservoir.*—The T.C. has instructed the Surveyor to proceed with the construction of a new reservoir.

Ramsgate.—*Tennis Courts.*—The T.C. proposes to spend £1,000 on the construction of hard tennis courts.

Redditch.—*Road.*—The U.D.C. proposes to construct a new road from Plymouth Road to Birchfield Road, Headless Cross.

Rochdale.—*Sewage Works.*—The Corporation has decided to carry out extensions at the Roch Mills sewage works at an estimated cost of £75,000.

Rotherham.—*Sewage Works.*—The T.C. is considering the further extension of the sewage works, at an estimated cost of £22,000.

Scarborough.—*Sea Defence Works.*—The Corporation has put before the Works Committee a scheme for the development of Peasholm Gap. The estimated cost is £64,000.

Selby.—*Bridge.*—The U.D.C. proposes erecting a bridge 40 ft. wide over the dam to connect Gowthorpe with Flaxby Road. The estimated cost of an iron bridge is £7,400, and of a concrete bridge, £5,900.

Sheffield. — *Wall.* — The Corporation Estates Committee has decided to erect a mass concrete retaining wall, at an estimated cost of £1,900.

Southend-on-Sea. — *Road.* — The T.C. has decided to construct a road at a cost of £30,000 on the north and east boundaries of the borough.

Stoke-on-Trent.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £20,000 and £15,000 respectively for sewerage and sewage disposal works for Burslem and borough districts.

RECENT PATENT APPLICATIONS.

184,846.—H. Wade (Blaw Knox Co.): Towers, poles, masts, and derricks.

184,906.—D. Whitaker: Power-navvies and excavating machines.

184,909.—F. Mossberg and Mossberg Pressed Steel Corporation: Beam heads.

185,014.—A. Bouhardi: Building blocks.

185,222.—W. E. Clifton, J. S. Ewart and Clifton Ewart Construction Co., Ltd.: Concrete structures.

185,255.—R. MacGregor: Concrete quay wall construction.

185,317.—G. Jaeger: Concrete mixers.

185,529.—Sabulite (Great Britain), Ltd., J. Bellingham and W. H. McCandlish: Machines for moulding and pressing concrete and similar material.

TRADE NOTICE.

The Cleethorpes Urban District Council has placed a contract with the Walker-Weston Co., Ltd., for the supply of their patent interlocked double-layer reinforcement in connection with the reconstruction of the main Grimsby Road at Cleethorpes.

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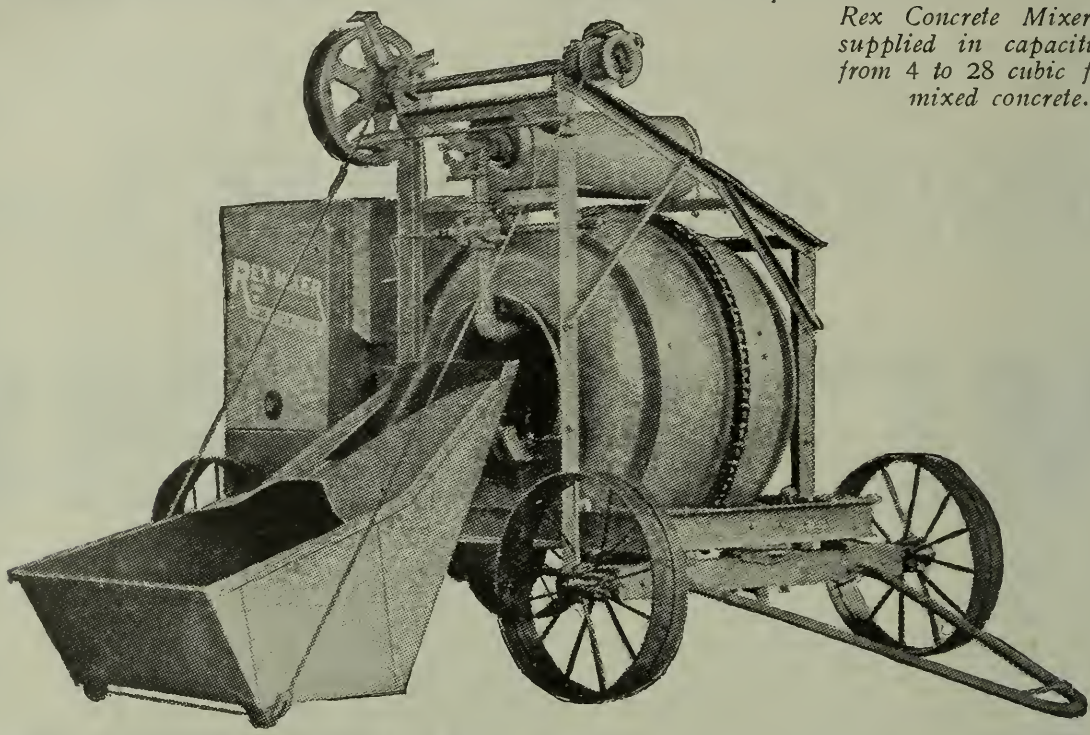

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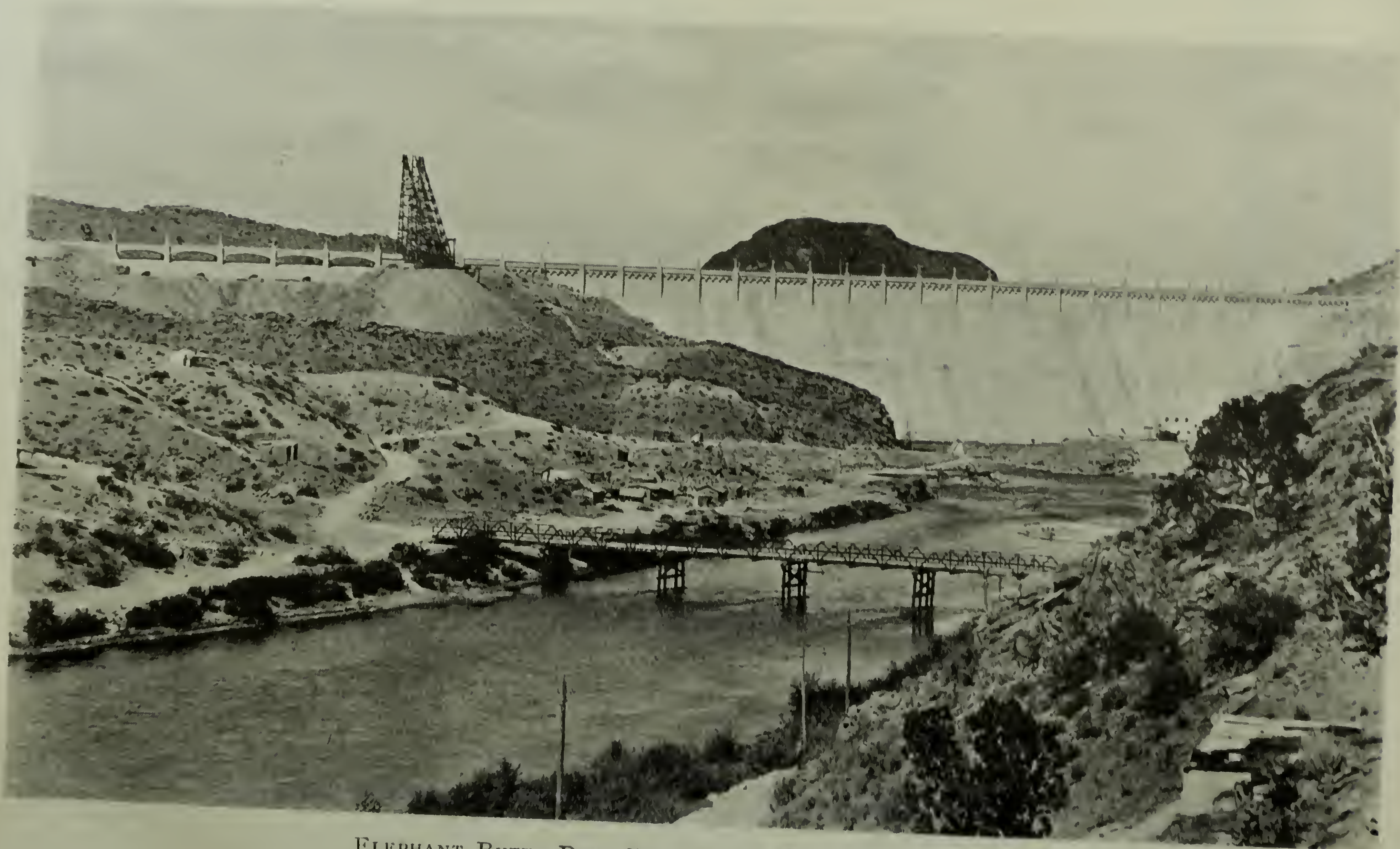
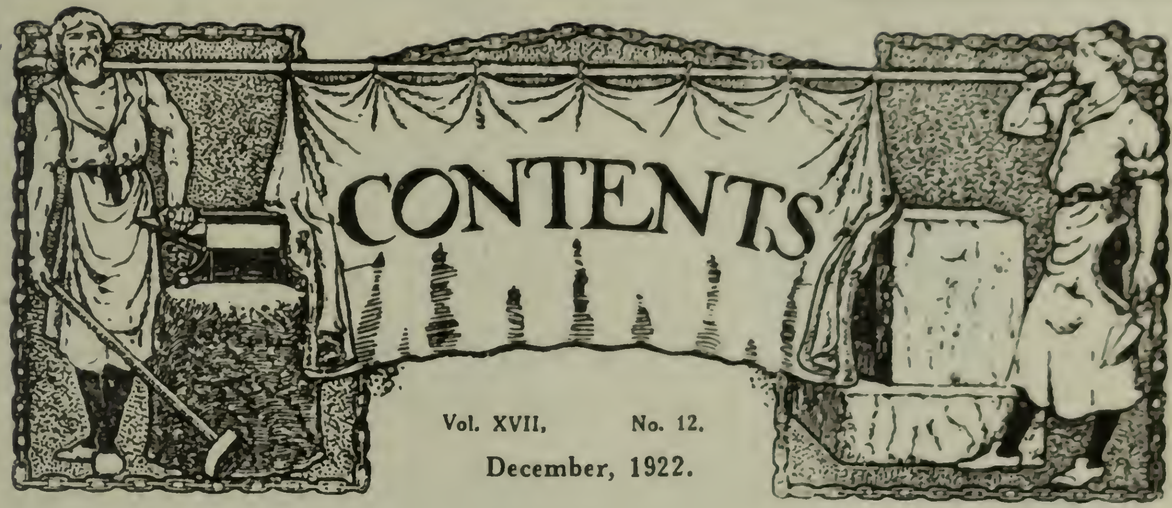


Elephant Butte Dam, Rio Grande Project. (*See p.* 763.)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Vol. XVII, No. 12.
December, 1922.

CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

Volume XVII. No. 12. LONDON, DECEMBER, 1922.

EDITORIAL NOTES.

THE CONSISTENCY OF CONCRETE.

THOSE who have had the opportunity of observing the rapidity of hardening and the general improvement in strength of concrete made with the minimum of water compared with the sluggish hardening and slow development of strength of what is so expressively termed "sloppy" concrete will have received an object-lesson that will make them enthusiastic advocates of stiff concrete. But such terms as "quaking consistency" and "no excess of water," which are used to specify the wishes of such advocates, are capable of varying interpretations, and the need for a standard measure of consistency has been pronounced. For this purpose the slump test, to which we refer in detail on another page, appears to be entirely satisfactory. The apparatus required is simple and cheaply constructed, but it is efficient in maintaining uniformity in the consistency of concrete.

If a stiff concrete is required the "slump" should not be more than 2 in., and concrete of this consistency will require punning or rodding. For concrete which will flow around reinforcement the slump may be 6 in., or even more with intricate reinforcement. It is well to emphasise that the value of the test lies in the uniformity obtainable. For example, if instructions are given that a "concrete which will flow" must be used, the possibilities of variation lie between a concrete with the minimum amount of water to permit of flowing and a concrete with perhaps 50 per cent. more water than the minimum, resulting in a weaker concrete in inverse ratio. On the other hand, if it is first demonstrated that a flowing concrete suitable for the work coincides with, say, a 6 in. slump, the adoption of this standard will prevent any unnecessary excess water being used, and other things being equal a concrete of uniform strength should result. The slump test does not provide information as to the amount of water that must be added to any given batch of concrete to produce a given consistency; at the present time such data can only be obtained by experiments of a trial and error nature, although it is not unlikely that by further research it may be possible to develop a method that will enable the volume of water required for each slump to be determined.

The slump test is surprisingly sensitive and delicate—we have seen some results which show that an increase of the total water content in a concrete batch from 8 per cent. to 9½ per cent. caused the slump to increase several inches. Such an increase in the water percentage may appear insignificant until it is appreciated that from 8 per cent. to 9½ per cent. means an increase of nearly one-fifth in the water content, and that whereas in the 8 per cent. concrete the proportion of water to cement is 50 per cent., in a 9½ per cent. concrete this proportion is 60 per cent. These facts have to be considered in the light of the experience that the strength of a concrete is dependent on the ratio of water to cement. The greater the ratio of water to cement the less is the strength of the concrete.

The slump test is an essential feature of the tables for proportioning concrete that were published in our October and November issues, and we hope to see the test widely adopted and recognised as an essential feature of concreting work. A description of the test is given on page 791.

THE LOAN PERIOD FOR REINFORCED CONCRETE.

THE letter in this issue advocating that loans on reinforced concrete structures should be for as long a period as those for mass concrete, and the energetic steps proposed in regard thereto, raises some interesting points. Is reinforced concrete as permanent as mass concrete? The answer of most careful and conservative engineers would probably be that in favourable circumstances it seems to be so, but that our experience with reinforced concrete does not extend back so far as with plain concrete. By favourable circumstances is meant circumstances where the concrete is first class, made rich enough to be watertight, where only non-porous materials have been used (which excludes broken brick and many broken stones), and where the workmanship and supervision have been above suspicion. It is quite clear that with a porous concrete, or one with insufficient cover, it is only a question of time when corrosion will occur. This time may be long in the case of the inside of buildings in the dry, and short in the case of structures exposed to weather, and shorter still if exposed to sea-water or certain other damaging agents. The introduction of metal inside the concrete obviously introduces an element of risk which is absent in plain concrete. There have been cases in which rods in reinforced floors have corroded in three or four years as a result of the attack of calcium sulphate solution reaching them from a patent plaster. It is true that these are instances of insufficient cover and bad design or workmanship, but it has to be remembered that with mass concrete this danger would not have existed. There are many cases in which the loan period for a reinforced concrete structure might with advantage be increased, but there are also cases when the guarantee of good design, specification and workmanship is somewhat problematical, and unfortunately some reinforced concrete structures have been erected under conditions which invite early decay. Although such buildings are the exception rather than the rule, and are the result of not employing a competent engineer, the growing appreciation of good and careful design will undoubtedly ensure that they are not repeated. While, therefore, a sane review of the position is desirable, it is perhaps a little unfair to decry as " unjust, unreasonable and wasteful " the methods of a Government department which has perhaps been a little careful with a new material, and whose carefulness has in some cases been proved to have been desirable. The most important step to take for those who are interested in extending loan periods is first to ensure that no reinforced concrete structures are erected which are improperly protected against corrosion, overstress, temperature and contraction cracks, etc., and we have still to ascertain whether the Government department concerned would not then deal with a new state of affairs in a more generous spirit.

CONCRETE AND FIRE RISKS.

FURTHER evidence of the reduced fire risk which accompanies the use of concrete in building construction has just come to hand from America, in the form of an account of a fire which occurred recently at one of the buildings of the Pennsylvania State College in which is accommodated the Department of Horticulture. A considerable amount of highly-inflammable chemicals was stored in the building, and the fire commenced in the top story owing to an accident whilst a flask of ether was being heated by one of the chemists. A photograph taken after the fire, however, shows that only the top floor of the building was affected. This portion was in fact gutted, only the concrete floor preventing the flames from spreading downwards and completely destroying the structure. This is one of the instances which, coupled with many others, such as the case in London recently in which a fire in a City building stocked with celluloid was confined to the basement where it originated solely by the concrete floor of the story above, convincingly prove that concrete is the most fire-resisting building material. Experiments and tests are being carried on both in this country and abroad with a view to producing a concrete with still greater fire-resisting properties, but the experience of actual fires should be sufficient to demonstrate to the building public that a concrete building is the safest in which to invest their money. Commercial building, whether for personal use or rental, is an investment in which, if concrete be used as the medium of construction, any possible loss of income or disorganisation of business through fire can be reduced to the minimum. No material commercially possible for building construction at the present time is actually proof against fire, but it is surely in the interests of the building owner and the public generally that damage and loss of life should be guarded against by the use whenever possible of the most fire-resisting material known when it is available at competitive prices with other materials. Since writing the above, we have received a copy of a local paper containing some remarks of the Chief Officer of the Bath Fire Brigade on a fire which occurred last month in the Surveyor's Department at the Bath Guildhall, in the course of which he says: "Beneath the floor of the Surveyor's Department is two inches of concrete. This prevented the flames piercing the ceiling into the Town Clerk's office, which would certainly have been involved but for the fire-resisting floor."

CEMENT RESEARCH.

THE Report of the Committee of the Privy Council for Scientific and Industrial Research for the year 1921–22 reveals the fact that large sums of money are being spent on research work in connection with building materials (especially Portland cement) and methods of construction. The expenditure of the Building Research Board during the year under review was £10,323, and apparently the whole of this amount was derived from public funds. The amount of the Government grant to the British Portland Cement Research Association during a period of three years was £9,540, and the corresponding expenditure of the Association was probably double this sum because the funds of the Industrial Research Associations are made up of subscriptions from manufacturing firms in the industry and a Government grant of equal or less amount. The investigations by the Building Research Board, which has a Research Station at East Acton, include the experimental production of cement, the testing of firebricks, studies on the consistency of concrete, economy in brick burning, the use of corrugated asbestos-cement sheeting, etc. The results of some of the research work have been published from time to time, and it may be assumed that this course will continue to be adopted seeing that the work is being done with public money.

In the case of the British Portland Cement Research Association there has been no public issue of reports, and the results of investigations are communicated to the members of the Association alone. There is, of course, no alternative to this but publishing the results, whereby the whole of the world would reap the advantage of expenditure defrayed by a limited number of British manufacturers. The Privy Council Report, however, throws some light on the work of the Association and the benefits derived from it. Reports from four manufacturers are cited, each acknowledging indebtedness to the Association for its designs of mechanical appliances connected with kilns and its assistance in connection with scientific management. In one case a saving in fuel worth £25,000 a year is mentioned, and in another case a saving of 300 to 400 tons of coal a year with a 10 per cent. increased output is also attributed to the research improvements. These savings must ultimately benefit the consumer of cement, if indeed they have not already had some bearing on the price reductions that have occurred, and the Government aid to the Portland Cement Research Association seems to have been well justified.

The Portland cement makers of America have not been idle in the matter of research work as applied to their industry, and the Chairman of the Research Committee of the Portland Cement Association in that country recently reported that various manufacturers were already saving coal at the rate of 400,000 tons a year, due to utilization of heat hitherto wasted up rotary-kiln chimneys, and that it was expected that ultimately two million tons of coal a year would be saved by American cement manufacturers by adopting the recommendations resulting from research in connection with waste heat boilers connected with rotary kilns, the insulation of rotary kiln shells, and the pre-heating of air for combustion in rotary kilns.

PRICES FOR CONCRETE WORK.

ALTHOUGH it is still impossible, as in pre-war days, to base estimates for building work on the assumption that current prices of materials and labour would remain practically stable for some time ahead, the violent fluctuations in prices of all commodities which have so much hampered business during the past seven or eight years are now, we hope, over. The present trend of prices indicates that the movement towards the post-war normal will be of a steady nature if it is not disturbed by strikes or lock-outs, and, although it is still difficult, estimating for building work is not the impossible proposition it was a short time ago when the cost-plus-profit form of contract was practically the only building code in use on large works. Now that " current " prices are current for at any rate more than a day or two, we have introduced a new feature in the form of schedules of prices for concrete and reinforced concrete work and materials used therein (see page 819), which we hope will be of value to our readers. The prices, which will be revised each month, where necessary, do not pretend to be the rock-bottom figures at which materials can be bought, but are a fair average for good quality materials purchased through the usual channels.

CONCRETE STRUCTURES ON THE RIO GRANDE PROJECT.

By L. M. LAWSON, Engineer, U.S.R.S.

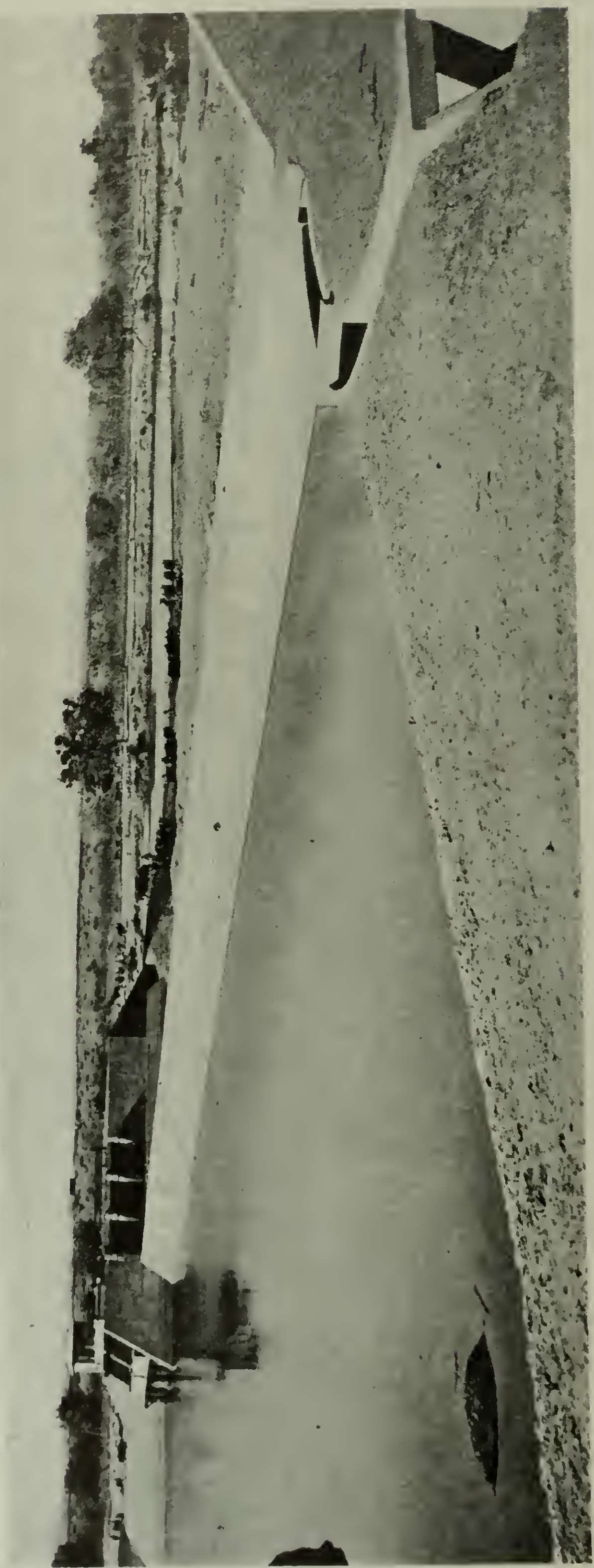
One of the principal projects to engage the activities of the United States Reclamation Service has been the Rio Grande Project on the Rio Grande, which is one of the principal rivers of the south-west arid region of the United States. Similar in characteristics to other rivers and streams of the desert country, its flow is erratic, and periods of low and insufficient discharge are followed often by years of large run-off, making dependent irrigation unsatisfactory and unprofitable. The feasibility of constructing a large reservoir to store the discharge of the Rio Grande and make it available for diversion on the irrigable area below was determined soon after the passage of the National Reclamation Act. These plans created an international as well as an interstate project, since a considerable area to be irrigated lies in Mexico on the south of the Rio Grande. The area now included as a part of the Rio Grande Project, comprising lands of the Rio Grande Valley in New Mexico and Texas, and the Republic of Mexico, is approximately 180,000 acres. In brief, the irrigation plan is the storage of water in a reservoir created by the Elepnant Butte Dam ; its discharge through this structure into the river, using the river as a carrier canal ; and the diversion of the water from the river by the construction of diversion dams at several points within the limits of the project.

ELEPHANT BUTTE DAM.

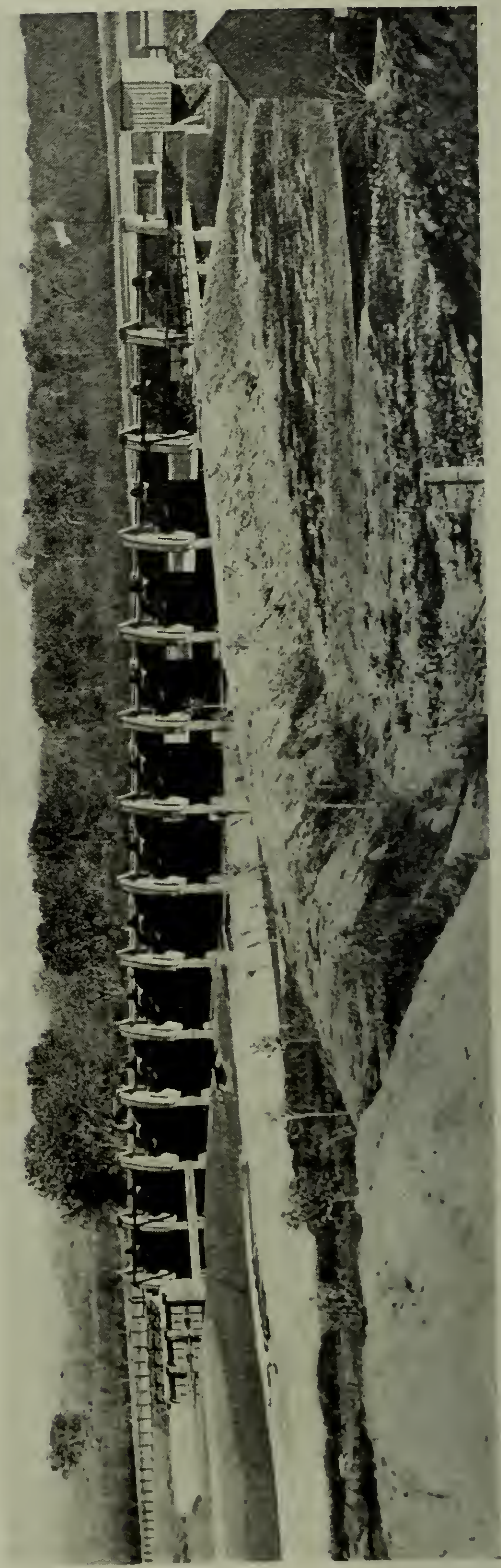
Elephant Butte Dam is a straight gravity structure, built of concrete. Its maximum height, from the deepest excavation to the top of the parapet wall, is 306 ft. It has a width of base of 215 ft., and contains approximately 600,000 cu. yds. of concrete masonry. This structure provides for the storage of over 2,600,000 acre ft. of water, and creates one of the largest artificial reservoirs in the world. A spillway 400 ft. long is provided at the west end, and in addition a controllable spillway is provided consisting of four 10-ft. diameter cylinder gates which can be operated and used to regulate the waste waters from the reservoir and prevent damage throughout the project by reducing the volume of discharge to that which will not overflow the river banks. The outlets for discharging water through this structure are of special design, and include the use of balanced valve gates, 5 ft. in diameter. Service gates admit water from the reservoir into a chamber from which the flow is regulated by the balanced valves. All the gates are installed in a separate structure near the east side of the dam.

Active construction work was started in July, 1910. The first concrete was placed in the dam in June, 1913, and the structure, which cost approximately 5,000,000 dollars, was complete and in operation in 1916. In the construction a number of features were introduced to prevent percolation of water under the foundations, the principal feature being a cut-off trench at the heel of the dam. In the bottom of this trench a row of holes was drilled, 10 ft. apart and 50 ft. deep, through which grout was forced effectively to seal openings that might exist in the natural formation. In addition, a series of drainage wells was provided 8 ft. apart the entire length of the dam, and extended upward to a gallery where measurements of the percolating water could be made showing the outflow discharge below the dam. Besides the precautions to prevent the underground percolation and seepage, the entire upstream face of the dam was coated with a cement mortar by means of a cement gun. This mortar was one part Portland cement and two parts sand, and forms a coating approximately 1 in. in thickness.

The main portion of the structure is built of sand-cement concrete, in which was placed large quarry stones, making up approximately 20 per cent. of the volume. This material was placed, and the excavations largely made, by three cableways, each with a span of about 1400 ft. Power was furnished for the mixing plant, cableways, and other requirements by a steam plant directly connected to generators and transmitted to the works at low voltage. The placing of this large volume of concrete permitted the use of a manufactured "sand-



Percha Division Dam.



Mesilla Diversion Dam.

CONCRETE WORK ON THE RIO GRANDE PROJECT.

cement," and effected a saving of over 200,000 dollars in the cost of the dam. All Portland cement used in the manufacture of sand-cement was purchased under United States Government standard specifications. It was re-ground with an equal part of sandstone to form sand-cement, and used in that form throughout the dam in the same manner as ordinary cement. This re-ground sand cement was inspected and tested regularly before being used in the work.

The concrete made consisted of an intimate mix of river sand, taken from the excavation for the dam or run of crushed rock, and sand-cement in proportions determined by frequent chemical analyses of the ingredients. The proportions approximated 1 part sand-cement, 3 parts sand, and 6 parts rock. Particular stress was laid upon obtaining a carefully-proportioned mixture which would have the greatest possible impermeability. The total amount of sand-cement manufactured amounted to approximately 625,000 barrels.

LEASBURG DAM.

The first diversion dam of the project was constructed in 1908. This consisted of a reinforced concrete weir resting on piles, and two cut-off heels of sheet piling. The weir proper is about 10½ ft. high. The toe of the dam extends a distance of 30 ft. from the up-stream face in an apron of reinforced concrete 2 ft. in thickness, and the end of the apron is protected by loose rock which extends a distance of 15 ft. down-stream. The construction of this feature was carried out by contract.

MESILLA DAM.

The second dam built is the Mesilla diversion dam, in the centre portion of the Mesilla Valley, approximately 20 miles below the Leasburg Dam. Its function is the diversion of water from the Rio Grande into the two main canal systems on each side of the Mesilla Valley. The river banks at this location were very low, and provision was necessary in the design for permitting discharge of the entire river through the structure. This was effected by installing on the concrete crest of the dam, which was laid 4 ft. below the normal river bed, 13 Taintor gates. The sluiceways of the dam consist of four of these gates, each approximately 21 ft. long. The main portion of the dam consists of nine similar gates of the same length. The dam is 300 ft. in length between abutments, and also serves as a reinforced concrete highway bridge. The gates are operated by a gasolene engine mounted on a car which moves along the roadway of the dam on a track and engages the gates to be opened in turn.

Steel sheet piling 24 ft. long was used for coffer-damming the river on the side to be excavated. A portion of the excavation was performed by men and teams, and the remainder by a dragline excavator. Concrete of a 1 : 2½ : 5 mixture was transported in push cars on a trestle to all parts of the work. Sand and gravel used for concrete was obtained from the neighbouring hills, as well as the rock, and all hauled 3½ miles over poor roads to the site.

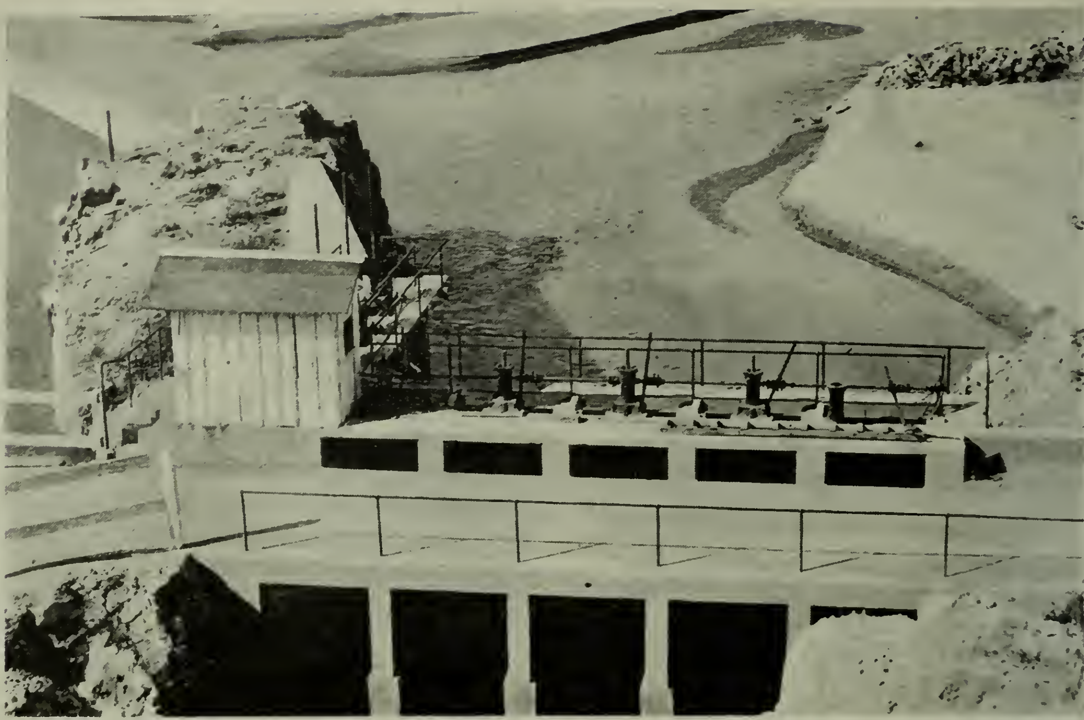
PERCHA DAM.

The Percha Dam is also of reinforced concrete, and has a crest of weir 350 ft. long. It is located on the Rio Grande about 25 miles south of the Elephant Butte reservoir. At the west end of the dam there is a sluiceway closed by two steel Taintor gates, each 8 by 20 ft. The height of the dam is 14 ft., with base set 6 ft. below the river bed. Below this level a cut-off wall of concrete and steel sheet piling extends an additional depth of 15 ft. The total width of the dam, up and down stream, including the apron and paving, is 103 ft.

Unlike the Mesilla Dam, but similar to the Leasburg Dam, practically the entire discharge diverted is supplied to one main canal

An interesting feature of the Percha Dam was its building outside of the river section, and the later diversion of the river over its crest when completed. The topography permitted such an arrangement, and the plan resulted in a considerable saving of cofferdam work and expense which would have accrued with the handling of the river during construction. Sand, gravel, and rock were obtained near the site, and were of good quality. Cement was hauled from the nearest railroad point, approximately 30 miles.

In addition to the main structures and diversion works, concrete structures play an important part in the project construction in smaller, but no less



Headworks of Leasburg Diversion Dam, Rio Grande Project.

important, features. In later years the increased cost of fabricated steel resulted in the use of reinforced concrete siphons instead of overhead flumes for river crossings of canals. Concrete has been used for other permanent types of canal structures, such as check gates and structures installed to take care of changes of grade made necessary by the topography.

Particularly in this locality, where a large percentage of alkali (or salts) are found in the soil, considerable care is necessary to be exercised in ensuring the cleanliness of the materials used. Where this is not done, and soil or water containing a large amount of alkali finds its way into the concrete, the permanency of the concrete is attacked and in numerous cases the effect of the alkali results in a honey-combing of the structure. The prevention of this effect lies in using a dense mixture of concrete free from silt and mixed with water comparatively free from high salt (or alkali) content. Where these precautions have been observed concrete has withstood the action of alkali successfully and no disintegration is perceptible.

A cement plant, operated by a private concern, is located at El Paso, and besides furnishing practically all the cement utilised for the irrigation features its product has also been used for the construction of county concrete roads, farm silos, and for the usual building construction purposes incident to the development and growth of the city of El Paso.

THE EFFECT OF MOISTURE CONTENT UPON THE EXPANSION AND CONTRACTION OF CONCRETE.

THE University of Illinois has rendered the concrete industry a further service in publishing Bulletin No. 126 upon "The Effect of Moisture Content upon the Expansion of Plain and Reinforced Concrete." The inherent property of contraction possessed by concrete has been recently referred to in this Journal,

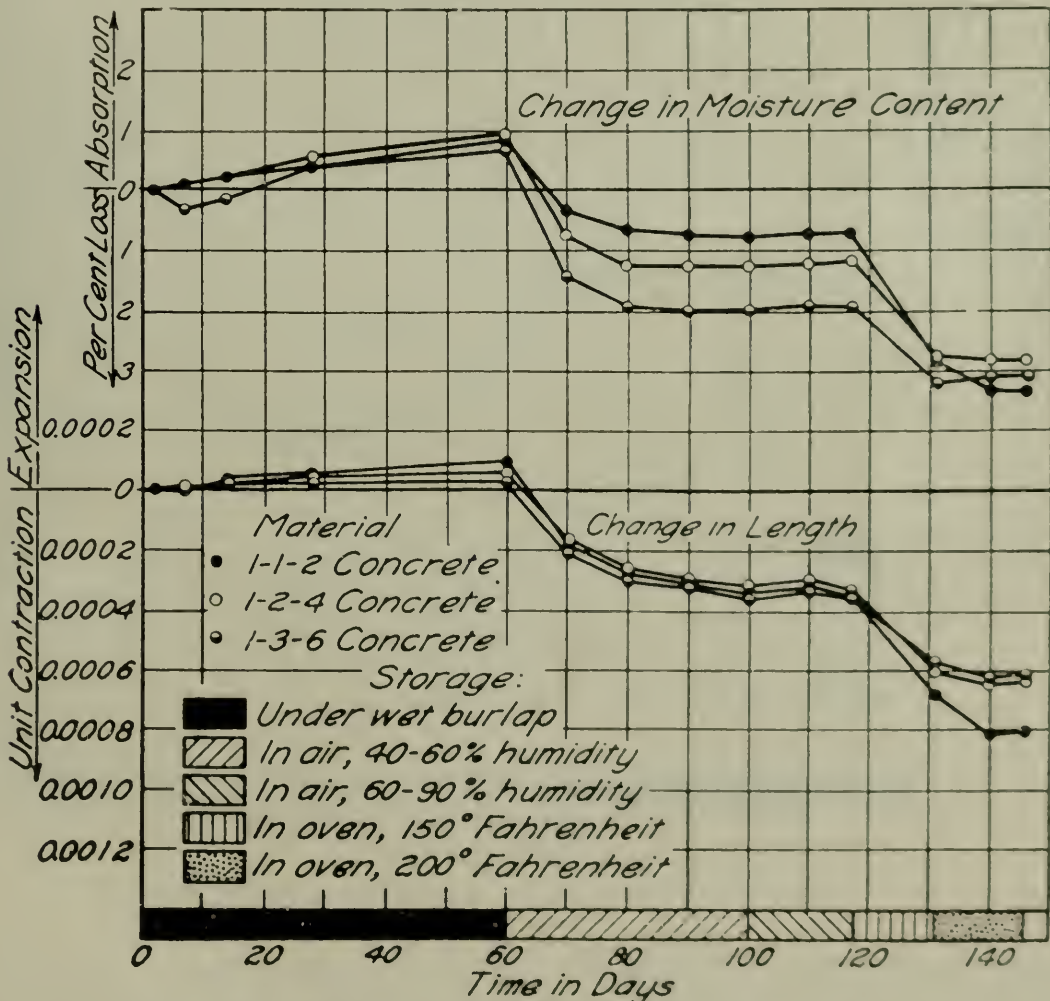


FIG. 1.—CHANGE IN LENGTH WITH CHANGE IN MOISTURE CONTENT OF MORTAR.

and the experiments recorded in this Illinois University Bulletin show in exact figures the amount of such contraction under various conditions, and also the stresses that may be caused when the concrete is reinforced, or is not free to move in every direction. The reinforcement of concrete with steel would not be so generally applicable, but for the fact that, so far as temperature changes are concerned, the coefficient of expansion of steel is practically identical with that of concrete, but unfortunately this does not apply to changes of volume with changes in moisture content, because while steel remains constant, whether wet or dry, concrete expands when wetted and contracts when dried. Hence, when reinforced concrete contracts during drying, tensile stresses are set up in the concrete and compressive stresses in the steel.

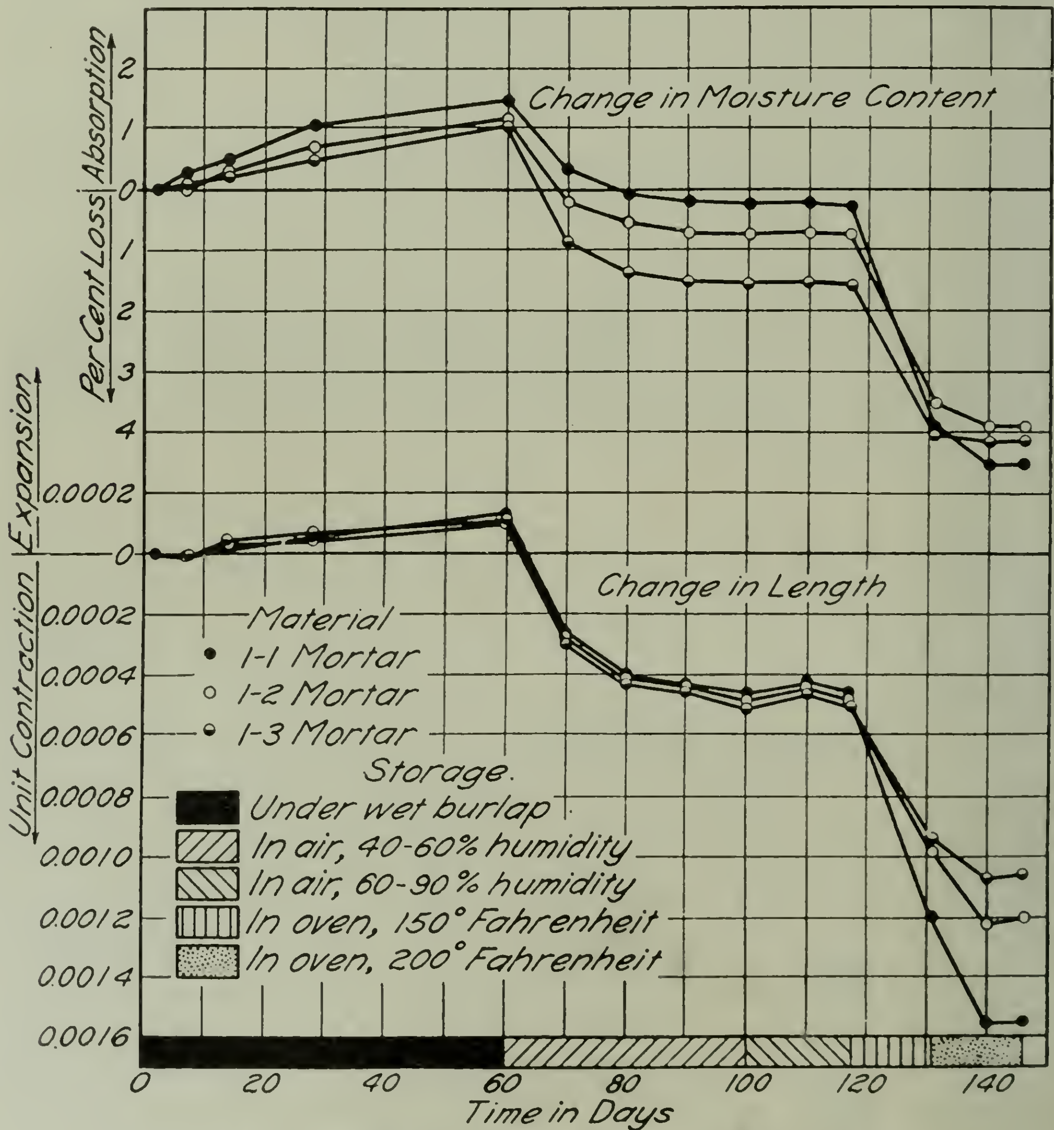


FIG. 2.—CHANGE IN LENGTH WITH CHANGE IN MOISTURE CONTENT OF CONCRETE.

The measurements of expansion and contraction of plain concrete were done on bars 2 by 3 by 24 in. in size with steel plugs at each end to permit of exact measurement. The initial measurements were taken on removing the bars from the moulds the day after preparation. Subsequent measurements were made after periods of storage under varying moisture conditions, all measurements being corrected for the effect of temperature change. The gain or loss of the concrete in moisture was ascertained by direct weighing of the bars, and although this procedure served the immediate purpose of the investigation it is to be regretted that no attempt was made to distinguish between moisture mechanically held and chemically combined, as such data might have thrown some light upon the process of cement hardening. *Figs.* 1 and 2 illustrate the changes in length of cement mortar and plain concrete bars during a period of 60 days' dampness, followed by 40 days in a steam-heated room of somewhat low humidity, 20 days in the same room but unheated, when the humidity (natural) increased, and 40 days in an oven at temperatures of 150° F. and 200° F.

Under conditions of dampness, there is a slight but continuous absorption of water with corresponding expansion reaching to about 0·01 per cent. or ⅛ in.

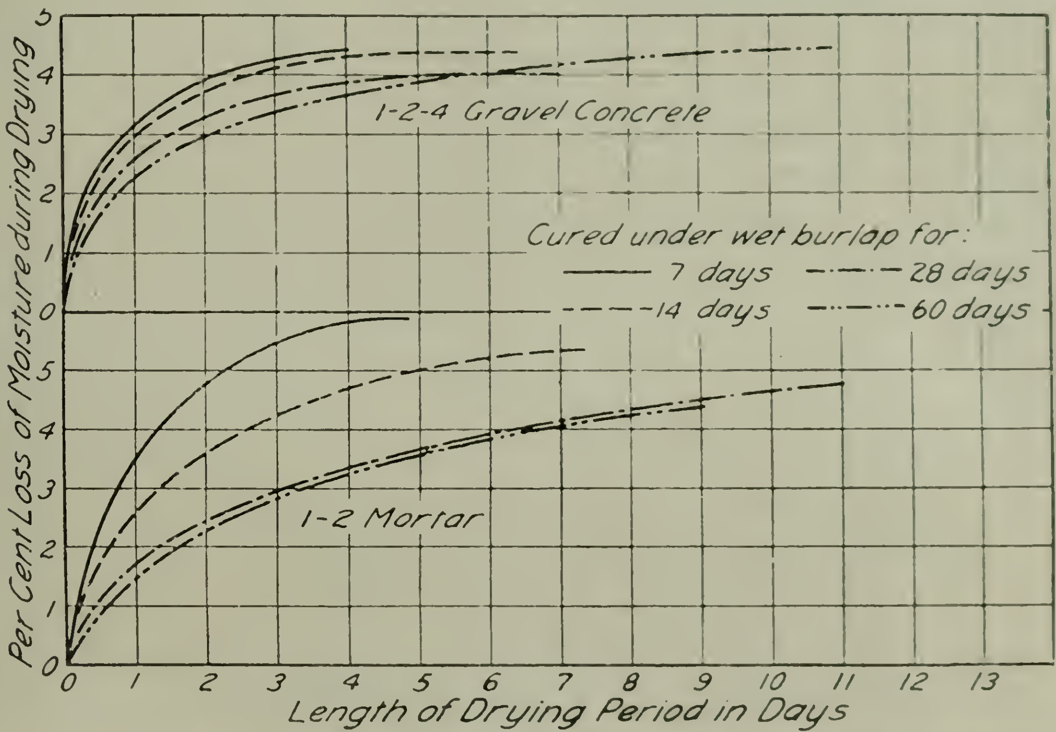


Fig. 3.—Loss of Moisture from Mortar and Concrete when dried at 150° F. after Preliminary Storage noted in Diagram.

per 100 ft. On transferring to dry air, there is a loss of moisture with a corresponding contraction reaching 0·05 per cent. in the case of mortar and slightly less for concrete. It should be noted that 1 : 1 mortar at 70 days, although containing more water than at 1 day showed a contraction, and this anomaly is probably connected with the state in which the moisture is held by the concrete. In the oven at 150° F. and 200° F., the loss of moisture and the contraction are considerable.

In a second series of tests, bars which had been kept damp for periods of 7, 14, 28 and 60 days respectively were dried at 150° F. until practically constant in weight and then immersed in water. *Fig.* 3 shows the loss of moisture by drying at 150° F., and it is seen that although the rate of drying of concrete varies with the age of the specimen, the total loss of moisture is the same in the end.

The rapidity of absorption and the corresponding rapid expansion shown in *Fig.* 4 when concrete dried at 150° F. is immersed in water are what might be expected, but the expansion, even after such drastic treatment, of 1 : 2 : 4 concrete after three hours' immersion is then only 0·01 per cent. or $\frac{1}{8}$ in. per 100 ft. extending to 0·03 per cent. in ten days.

Bars of sandstone and limestone having about the same porosity as the mortar and concrete tested, were submitted to the same drying and immersion

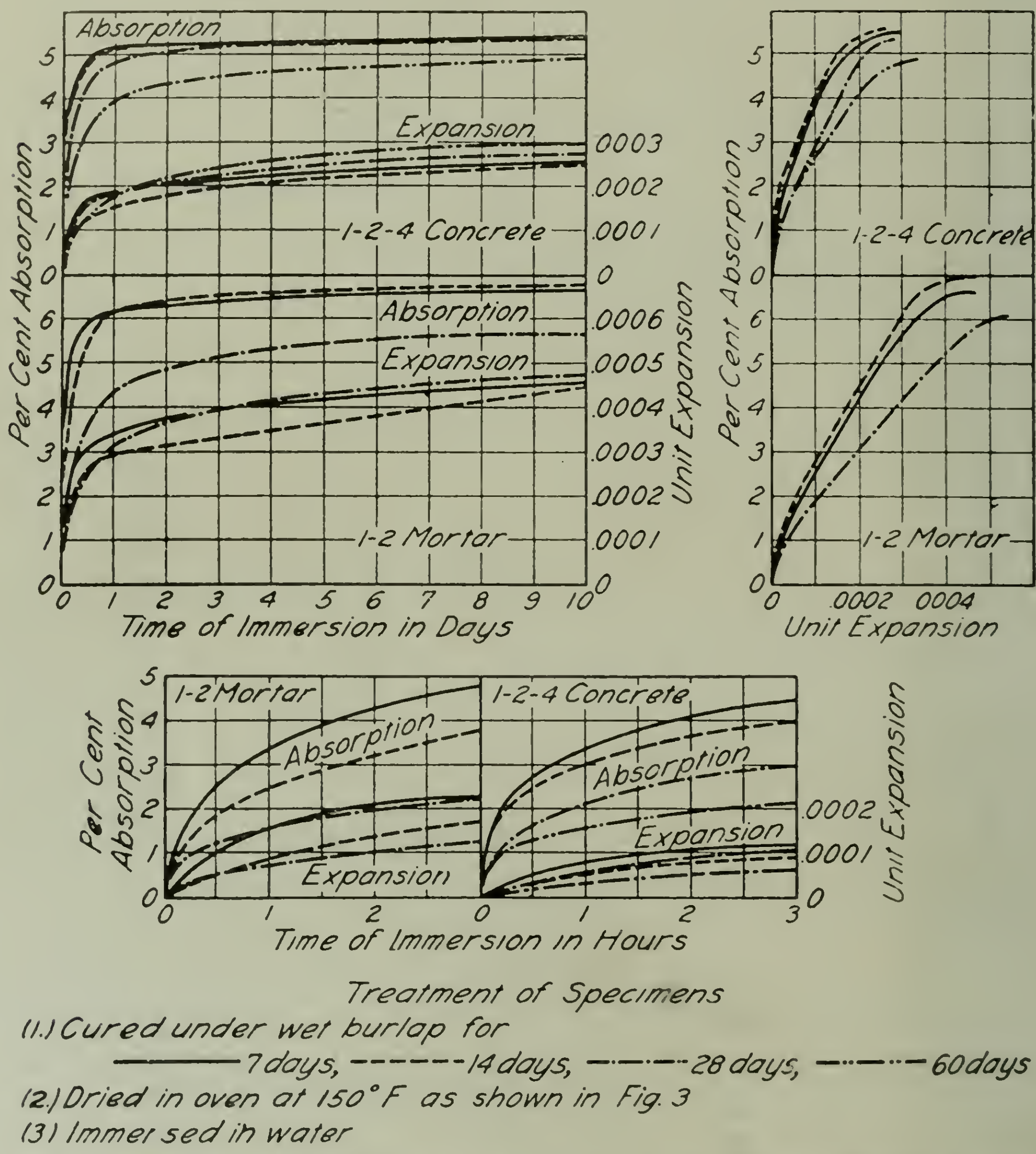


FIG. 4.—ABSORPTION AND CORRESPONDING EXPANSION OF MORTAR AND CONCRETE IMMERSED IN WATER.

treatment, and it was found that the sandstone expanded 0·08 per cent., or roughly three times as much as concrete, while the limestone, in spite of an absorption of 6 per cent., showed practically no expansion.

It can be proved mathematically that the shrinkage stresses in the steel and concrete of a reinforced concrete member are directly proportional to the amount of shrinkage in plain concrete, and the stress in the steel decreases, and the stress in the concrete increases with an increase in the percentage of reinforcement. Tests were made for the purpose of measuring the shrinkage stresses in reinforced concrete specimens. Concrete bars of the dimensions already stated were reinforced with two ⅜-in. round steel bars (3·68 per cent. reinforcement) and two ½-in. round steel bars (6·54 per cent. reinforcement) respectively and

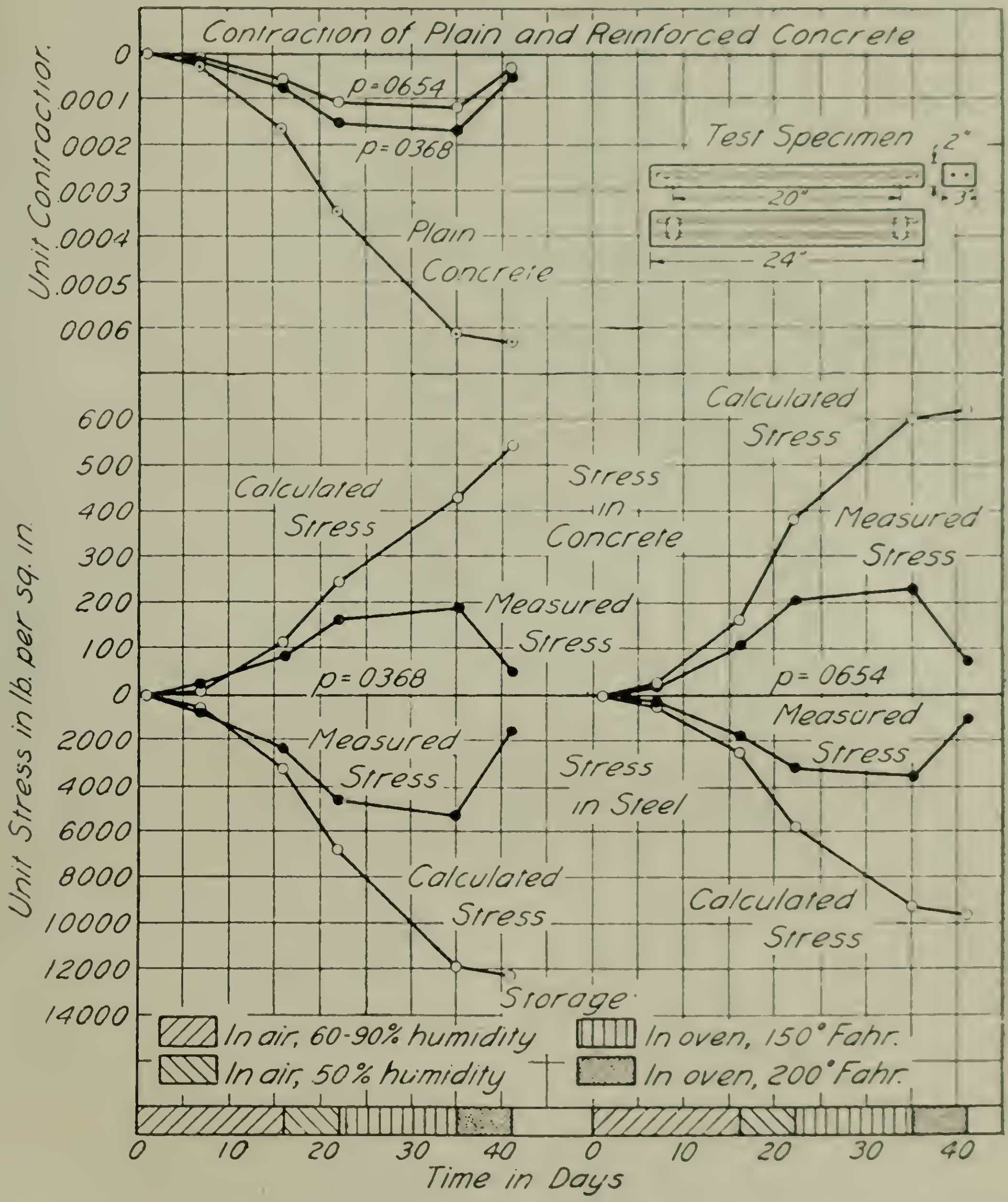


FIG. 5.—SHRINKAGE STRESSES IN REINFORCED CONCRETE SPECIMENS.

the contraction together with the measured and calculated stresses in the concrete and steel are shown in *Fig.* 5.

The changes of length were measured between points on each embedded steel bar and the measured stresses in the steel were obtained by multiplying the measured deformation in the steel by the modulus of elasticity of steel. The curves marked " measured stress in concrete " were obtained by multiplying the measured stress in the steel by the percentage of reinforcement and represent

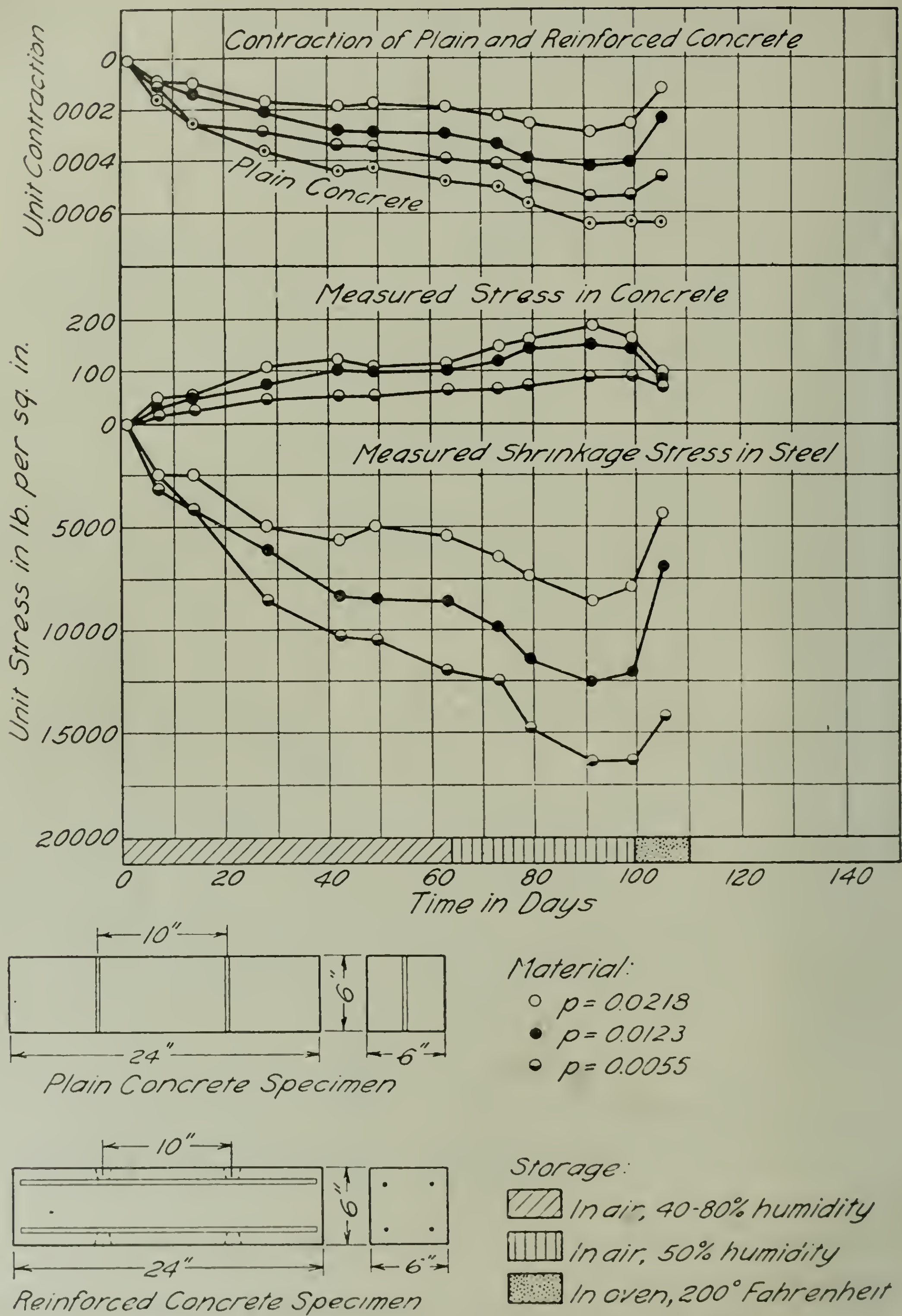


Fig. 6.—Shrinkage Stresses in Reinforced Concrete Specimens.

the average stress over the cross-section of the concrete. Even in concrete with a high percentage of reinforcement, there is an appreciable shrinkage leading to a tensile strength in the concrete of 204 lb. per sq. in. after twenty-two days in air with 6·54 per cent. of steel. After drying at 150° F. for thirteen days, the tensile stress in the same concrete reaches 240 lb. per sq. in., nearly corresponding to its

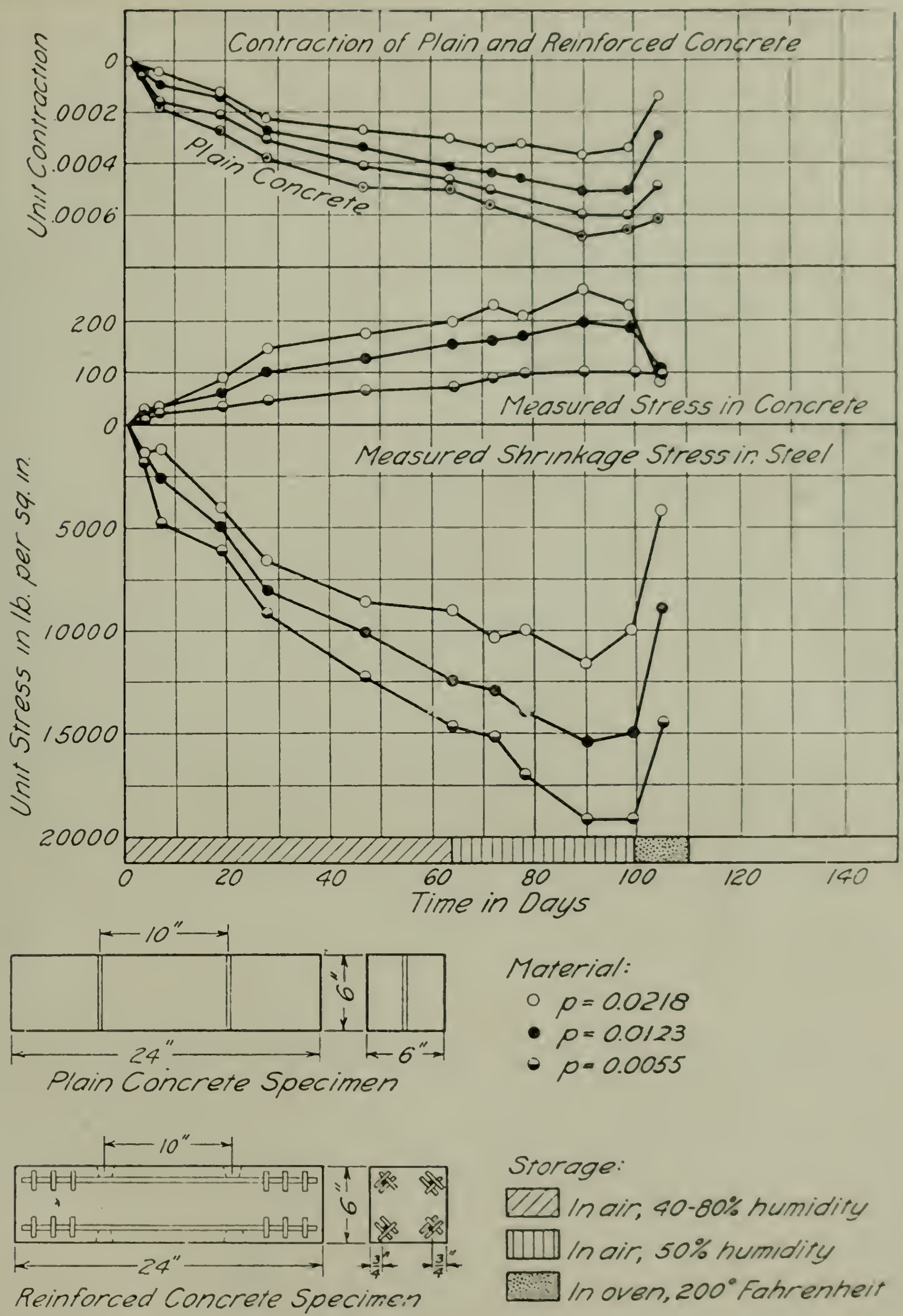


Fig. 7.—Shrinkage Stresses in Reinforced Concrete Specimens.

ultimate strength. On drying at 200° F., the concrete failed in tension and cracked as shown in the diagram by the sudden drop in the shrinkage stress.

Further tests were made with smaller percentages of reinforcement, viz. 2·18 per cent., 1·23 per cent., and 0·55 per cent. respectively, while in some cases the steel bars had three anchor lugs to prevent slipping. These specimens were kept in air for ninety-nine days and were then dried at 200° F. *Figs.* 6 and 7 show the contraction and the measured stresses in the concrete and steel.

The deformation in the reinforcing bars provided with lugs was greater than the deformation in the plain bar, thus indicating that slipping took place with the latter during the shrinkage of the concrete and showing that the shrinkage stress in the concrete is increased by good anchorage of the reinforcement.

During air storage, the measured stress in the steel reached 18,000 lb. per sq. in. when the percentage of reinforcement was 0·55 and the stress in the concrete reached 250 lb. per sq. in. when the reinforcement amounted to 2·18 per cent. In the one case, the stress exceeded the accepted working stress of soft steel, and in the other the ultimate tensile strength of the concrete was nearly reached. On drying at 200° F., the concrete evidently became injured, as shown by the drop in the stresses.

The results of these experiments go to afford overwhelming proof, if further proof be wanted, of the necessity of ignoring the tensile strength of concrete in the design of reinforced concrete structures. They also show that any calculations of the stresses in steel and concrete which ignore shrinkage stresses must be very far from the truth, at least up to the point when cracking of the concrete occurs. After this, the shrinkage stresses relieve themselves by such cracking and become of less importance. The high compressive stresses in the steel caused by shrinkage are of little importance in practice where it is usually stressed in tension, because they thus go to neutralise the normal stresses. This, however, is not so in the case of columns, where undoubtedly the effect of shrinkage is to make the steel stresses much higher than usually figured, and the concrete stresses much less, and, as a rule, shrinkage in columns occurs under conditions when no cracking and its consequent relieving of shrinkage stresses is likely to occur owing to the presence of externally applied compression stresses.

EFFECT OF CEMENT ON MARBLE FACINGS.

The gradual dimming of the polish of some marble slabs used as facings for concrete structures was recently examined. The loss of polish was found to be the result of chemical reaction; it was also accompanied by a scum which was clearly traced to the cement. Moisture in the concrete, and still more in the brickwork backing, gradually penetrated through the marble facing, carrying with it solutions of salts derived from the cement, which caused the defect. Only the thinner slabs of marble were affected, as the thicker masses of marble did not permit the percolation of the water. Pillars of reinforced concrete, to which the marble slabs were attached direct, without any intervening air-spaces through which the moisture could enter, showed the defect to a much smaller extent than brickwork, to which water had more ready access. The defect was most noticeable near the joints in the marble, i.e., in those places where moisture might be expected to have the most ready access. By preventing the access of moisture to the back of the marble all further production of the defect has been avoided.—*Tonind. Ztg.*

THE STREATLEY AND GORING REINFORCED CONCRETE BRIDGE.

The replacement of the bridge over the Thames between Streatley and Goring, will cause no regret to those interested in the preservation or enhancement of the beauties of the river, which the bridge now being built cannot but improve. After consultation with various architectural bodies, reinforced concrete was chosen as the medium of construction, primarily on account of economy of upkeep, but also because it was considered that the rural appearance of the neighbourhood could be maintained in concrete better than in any other material. The bridge is being built under the direction of Lt.-Col. J. F. Hawkins, M.Inst.C.E., County Surveyor of Berkshire, and Mr. A. E. Cockerton, P.A.S.I., County Surveyor of Oxford, by Messrs. A. Jackaman & Sons, Ltd., on the "Kahn" system of the Trussed Concrete Steel Co., Ltd., of Westminster. The following particulars of the design and construction are taken from a paper recently read by Captain A. C. Hughes, B.Sc. (Engineering Assistant to the Berkshire County Council) before the Berkshire Surveyors' Association :—

DESIGN.

The new bridge is in two sections, that on the Streatley side being 232 ft. long with six equal spans, while the Goring section is 355 ft. 6 in. in length with nine unequal spans. The work will be carried out in reinforced concrete throughout, with the exception of the handrail, which is in oak. Broadly, the principle is that of ordinary continuous beams supported at intervals by trestles and carrying a concrete deck slab. Normally the trestles are carried on nests of piles, but in two cases small foundation rafts have been laid, the subsoil being of a nature to warrant their use. The curved ribs are false and were included to meet the wishes of the various architectural bodies who intervened at the time when the re-building was first under consideration.

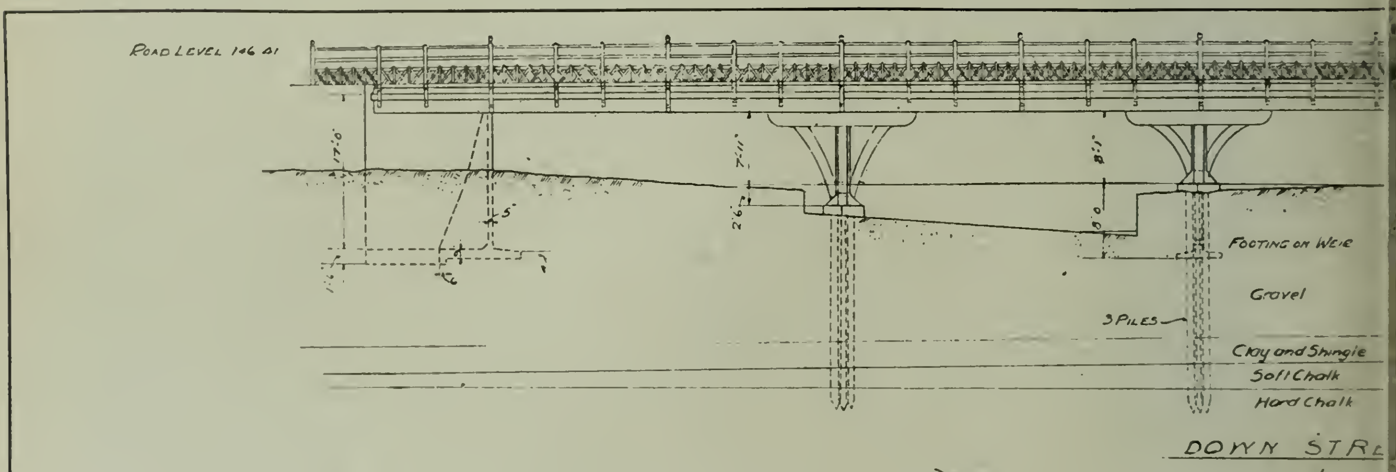
When the span is taken into consideration the beams are rather shallow, but the available depth was limited by consideration of headroom on the one hand and rise of the roadway on the bridge on the other. The end beams and slabs are free and rest on a thick bitumastic damp-proof material in order to provide an expansion joint, but it is problematical as to whether these joints will really fulfil their function.

The design load was that of two 16-ton traction engines passing in opposite directions, each hauling a 3-ton truck loaded with 9 tons of material ; 50 per cent. was allowed for impact. In order to deal with this loading, the equivalent distributed load to cause the same maximum moments and shears was found for each span. No attempt was made to investigate the moments arising from a series of concentrated loads, as the process would not have been justified considering the wide distribution of a point load, and the fact that the theorem of three moments is based on ideal conditions. The six-equal-span portion on the Streatley side presented no difficulty and the moments were easily found by calculation and checked by Griot's tables. In the case of the nine unequal spans on the Goring side, there was more difficulty. It was done by means of the coefficients given in the Appendix of Rankine's "Applied Mechanics" ; the moments arrived at by this method were checked in a number of cases by the graphical construction given in Claxton Fidler's textbook on Bridges and in every way compared most closely.

The abutments, which are in box form to reduce dead weight, were designed as a rigid frame subjected to a pull by the bridge when it contracted under a fall of temperature and a thrust from the earth pressure.

The stresses in the beams were calculated as for continuous girders, but to deal with the possibility of any support sinking, in every case the positive moments at the centre of the beams, considering them as freely supported, were found and sufficient steel provided at 28,000 lb. per sq. in. to deal with these moments. Ample reinforcement is provided for shear, the shear value of the concrete being entirely disregarded. The working stresses adopted were :—Concrete over supports, 700 lb. per sq. in. ; Concrete

FROM A DRAWING SHOWING THE BR



THE STREATLEY AND GOR
A Section and Plan of the G

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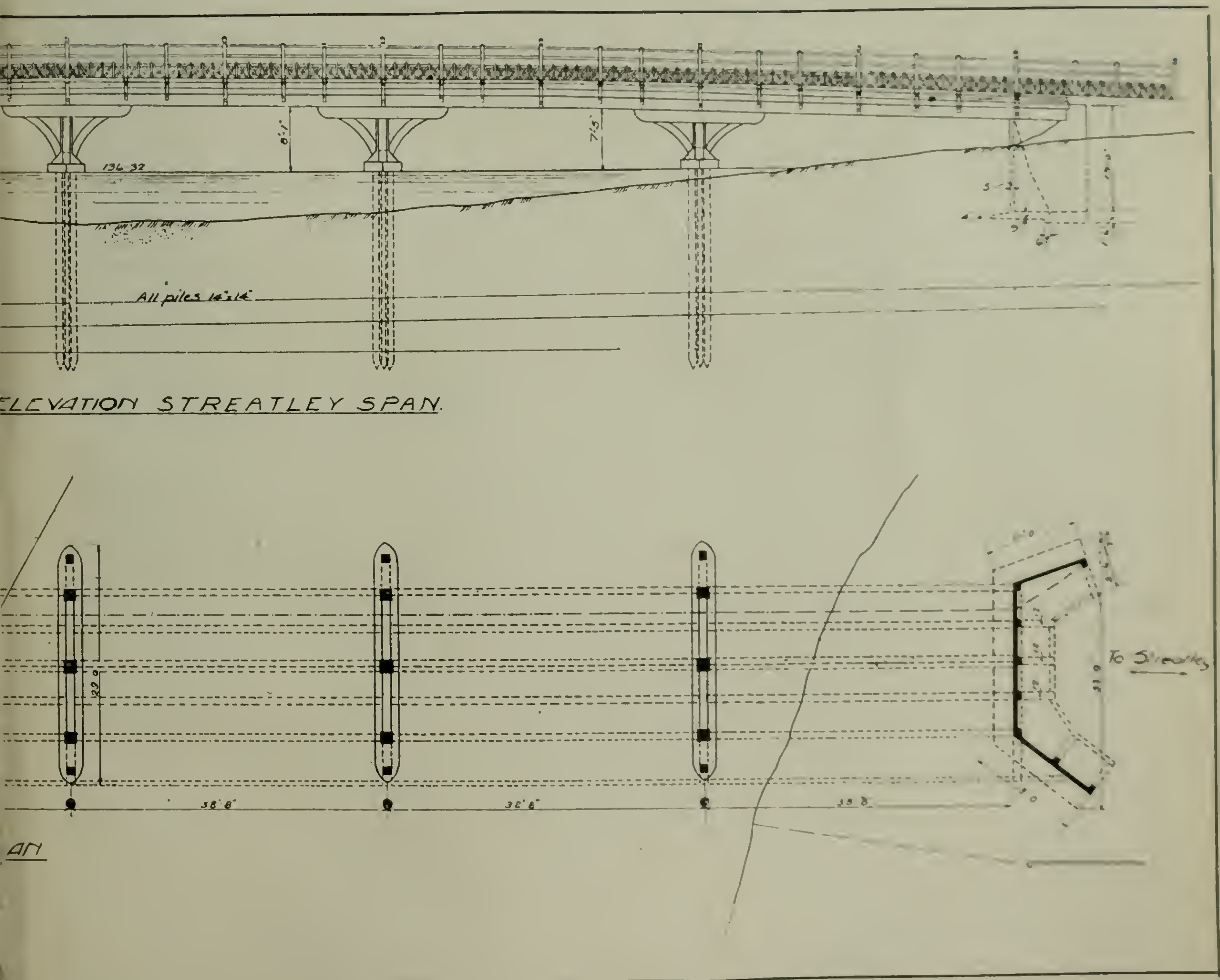


orced Concrete Bridge.

are given on pp. 792 and 793.]

in beams, 600 lb. per sq. in.; steel, in beam tops and bottoms, 16,000 lb. per sq. in.

The requirements of the Ministry of Transport with regard to the distribution of the load on the slabs being rather severe, the original slab thickness of 6 in. had to be increased to 7 in. under this restricted distribution, and the bars increased in number and reduced in diameter owing to the increased bond stress. In testing the bridge it is proposed to load one side and test the deflection on the other to find what measure of distribution really exists in a monolithic structure such as this, but at any rate it has been clearly established by reliable experiments that the old cone of 45 deg. is inadequate and too severe a restriction. The shallow beams mentioned before have necessitated the use of compression steel in practically every beam, and the severe negative moments at the supports were met by increasing the beam depths at these points.

PILING.

Previous to the preparation of the designs, borings were made at a number of points and "good chalk" was reported at uniformly varying depths. This "good chalk" proved most disappointing. Two trial piles 30 ft. long were driven at the commencement of the job and the first gave rather a poor result, the last 20 blows driving the pile 14 in., i.e. 7 in. in 10 blows, whereas the specification provides a set of 1 in. in 10 blows when a two-ton monkey is used falling a height of 42 in. It was discovered that the site chosen for the driving was occupied some fifty years ago by a mill pool, and a second pile was driven in another position within a few yards and a set of $\frac{7}{8}$ in. in 10 blows obtained. Unfortunately, as subsequent driving has shown, this was to prove almost the best set in the considerable number of piles now driven, except in cases where additional piles were driven to consolidate the ground. In only two cases has it been possible to obtain the specification set with the original number and length of pile, due to a conspicuous absence of "good chalk," and in some cases longer piles have been used and in others extra ones have been driven so as to distribute the weight. This was an essential precaution, as the maximum load per pile for the longest span was as high as 44 tons. It may be as well to mention here that the various pile formulæ in existence should be accepted with reserve, as most of them are based on the driving of wooden piles. A wooden pile almost invariably gives a bigger set than a concrete one under similar circumstances, the inertia of the concrete pile being much greater than the wooden. The piles are composed of three parts of ballast from $\frac{3}{4}$ in. to $\frac{1}{4}$ in., $1\frac{1}{2}$ parts of sand $\frac{1}{4}$ in. downwards, and one part of cement. Those on the Goring side were machine mixed, while those on the island were hand mixed. The piles vary in length from 22 ft. to 32 ft. and are fitted with iron shoes weighing 45 lb. The reinforcement consists of four $\frac{7}{8}$ in. bars with $\frac{1}{4}$ in. hooping. The average period between manufacture and driving was six weeks and the pile heads have in all cases stood well, showing good concrete and careful driving. The average number of blows per minute is 34.

TESTS OF CEMENT AND CONCRETE.

Sand and gravel are used for the concrete; the proportion for the main structure is 4, 2, 1, and for the columns 2, 1, 1. The voids in the aggregate (from $\frac{3}{4}$ in. to $\frac{1}{4}$ in. in size) are determined by the water method. The average figure has been 45·5 per cent., while that of the sand ($\frac{1}{4}$ in. and downwards) has been 41·7 per cent. It will be thus seen that a 4, 2, 1 mixture gives an excess of 4·5 per cent. of sand and (since in any case it is desirable to have a 10 per cent. excess of cement) a deficiency of 1·7 per cent. of cement. This represents a reasonably accurate grading. At the commencement, the percentage of fine material in the sand was too high and it has been necessary to restrict the quantity of sand passing a 50 by 50 sieve to 30 per cent. of the bulk of the sand. It would probably have been even better to limit this figure to 20 per cent. For standard Leighton Buzzard sand the percentage is about 15 per cent.

The cleanliness and grading of the aggregate and sand are carefully watched as the work proceeds, the Resident Engineer having a laboratory in his office. The following tests are made on the job:—

Samples are sieved through sieves of the following sizes in the case of the aggregate: $\frac{3}{4}$ in., $\frac{5}{8}$ in., $\frac{1}{2}$ in., $\frac{3}{8}$ in., and $\frac{1}{4}$ in., the object being to see when the results are plotted whether there is an even grading of particles (the curve being a straight line). In the case of the sand the sizes employed are :—$\frac{1}{4}$ in., $\frac{1}{10}$ in., $\frac{1}{20}$ in., $\frac{1}{50}$ in., $\frac{1}{100}$ in. and $\frac{1}{200}$ in. Up to now the results have been most satisfactory.

The voids are determined as mentioned above; this forms a check on the mixture.

The amount of silt is determined by :—
(*a*) Shaking up in a graduated flask, and
(*b*) Decanting from flask to flask and comparing the volume of the residue with the original volume.

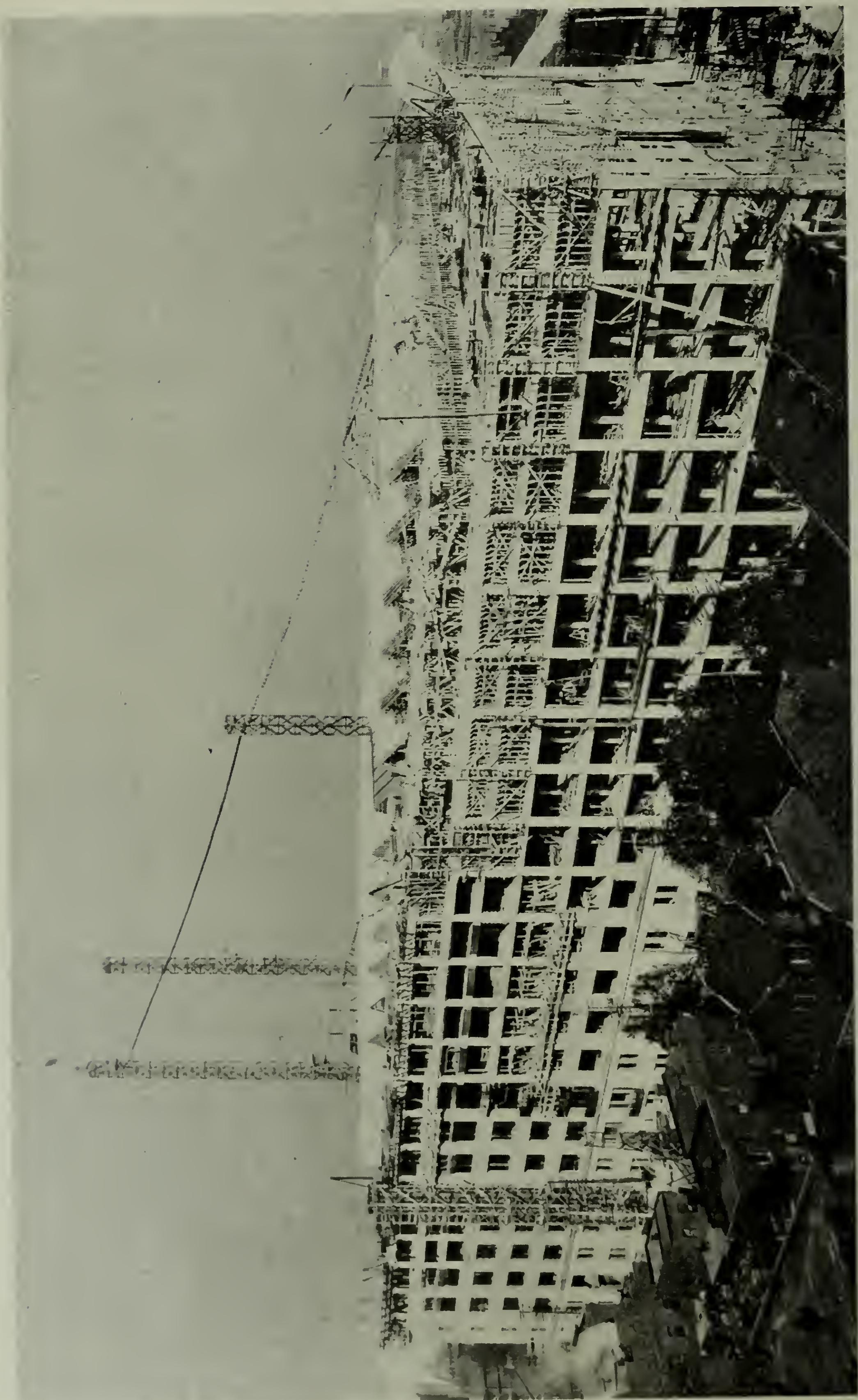
In the case of sand which has been properly washed the average percentage has been 1·15 per cent. of silt; all material passing a 200 by 200 mesh sieve being regarded as silt. There have been times when the percentage has been much too high, caused by lack of water at the pit. At least 500 gall. per cu. yd. of material per hour is required to wash thoroughly a clayey aggregate. An alternative method is to agitate the material in tanks and then allow it to settle. When the water has been drawn off, the silt can be removed from the top.

The quantity of water in mixing is tested by tamping concrete into a length of 6 in. C.I. pipe 12 in. long and then withdrawing the pipe to see how the material will stand on its own. About 6 gall. of water per cu. ft. of cement has proved the most satisfactory quantity.

The presence or otherwise of vegetable matter in the sand is tested by immersing a sample for 24 hours in a 3 per cent. solution of sodium hydroxide. Any colouring of the liquid other than clear water or light yellow would be rejected, but up to the present this has not been found necessary.

The cement is "Ferrocrete" and has given excellent results. The initial setting time has never been less than 1 hr. 32 min. When made up into 3 and 1 briquettes with sand from the job, one tensile test gave 226 lb. per sq. in. at 7 days and with standard Leighton Buzzard sand 356 lb. per sq. in. This would tend to show that the sand was not satisfactory. These briquettes were made from a rejected consignment and a further test of the same sand gave similar low results. Later, for the purposes of comparison, the same sand was tested after everything passing a 50 by 50 mesh sieve had been removed and this gave 299 lb. per sq. in., an increase of 32·3 per cent. Test cubes 6 in. by 6 in. by 6 in. are taken from every 50 cu. yds. of concrete and tested. The first batch, for the same reason as mentioned above, gave results which were not too satisfactory considering the care and attention which had been spent on the concrete. The average crushing strength at 28 days was 1,810 lb. per sq. in., which increased at 8 weeks to 2,740 lb. per sq. in. Better sand was then available and the next batch gave an average of 3,670 lb. per sq. in. at 28 days.

It should be emphasised that the sand from the job and cement test is by far the most important. Here, for example, is a first-class cement, a good clean aggregate, and careful mixing, but the first concrete made gives a comparatively indifferent result, due entirely, as subsequently found, to the presence of too much fine material in the sand. In general, it may be said that too much importance is attached to the shape of the particles of sand at the expense of the question of their size. The "sharpness" of the material affects the ultimate strength of the mortar in a much lesser degree than does the presence of too many fine particles. Smaller grains of sand have larger total surface than the same bulk of a larger grain and therefore require more cement to produce the same strength; moreover, it is more difficult to work the cement into the interstices of the finer material. Another important point is the even gradation of particles from the largest to the smallest.



Reinforced Concrete Bottling Building, St. Louis: During Construction (See p. 781.)

REINFORCED CONCRETE BOTTLING WAREHOUSE AT ST. LOUIS.

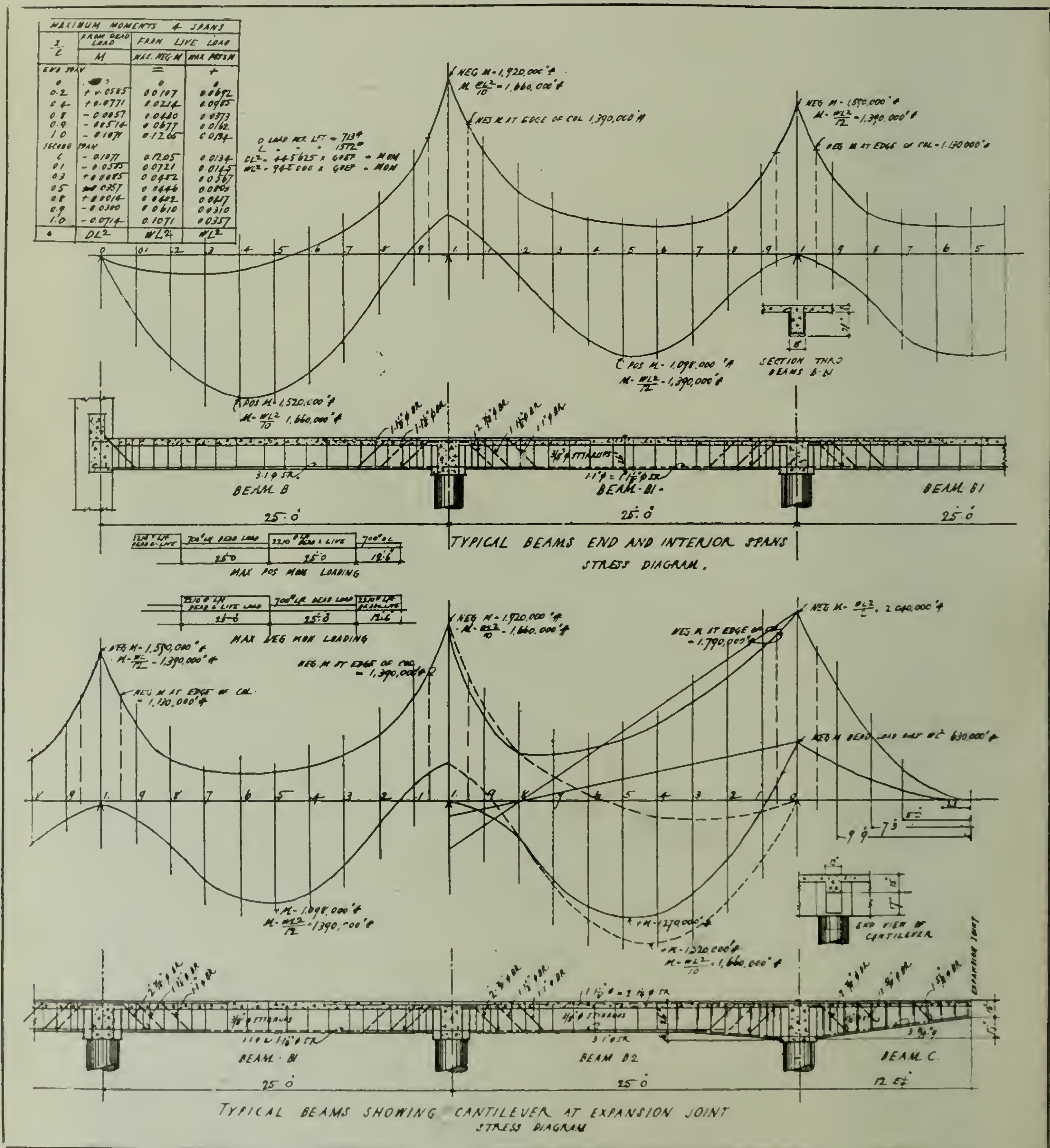
THE 601 ft. 10 in. by 252 ft. reinforced concrete building for the Bevo Bottling plant, St. Louis, recently completed, occupies with its subway an area of 173,000 sq. ft. and has a cubical contents of 21,932,000 cu. ft. It has one 26-ft. story below ground level and eight stories above the ground, with a total floor area of 1,117,700 sq. ft. It covers two complete city blocks and is served by 13 railroad tracks passing through the building. The building is used exclusively for the bottling, packing, storing, and shipping of "Bevo," which is made in the adjacent plant of the Anheuser Busch Co. and delivered to the building through pipe lines in a tunnel from which it is pumped to storage tanks on the fifth story. The concrete floors and columns are designed to support

REINFORCED CONCRETE BOTTLING BUILDING, ST. LOUIS: EXTERIOR VIEW ALONG BROADWAY.

heavy tanks and machinery, and to carry a uniformly distributed live load of 275 lb. per sq. ft. in panels of 16 to 25-ft. spans, thus making very heavy construction necessary.

The exterior walls have a 6-ft. granite base, Bedford limestone facing for the first two stories, and red mat brick in the upper stories. The cornice is of terra-cotta with wide overhanging terra-cotta brackets. All interior walls are faced with white enamelled brick.

The basement exterior walls, 3½ to 4 ft. thick and 30 ft. high, are of concrete



Reinforced Concrete Bottling Warehouse.

REINFORCED CONCRETE BOTTLING BUILDING, ST. LOUIS: TYPICAL INTERIOR VIEW, SHOWING EXPANSION JOINTS

gravity section cantilever type, designed to act as retaining walls and resist the exterior earth pressure without regard to the bracing effect of the street floor.

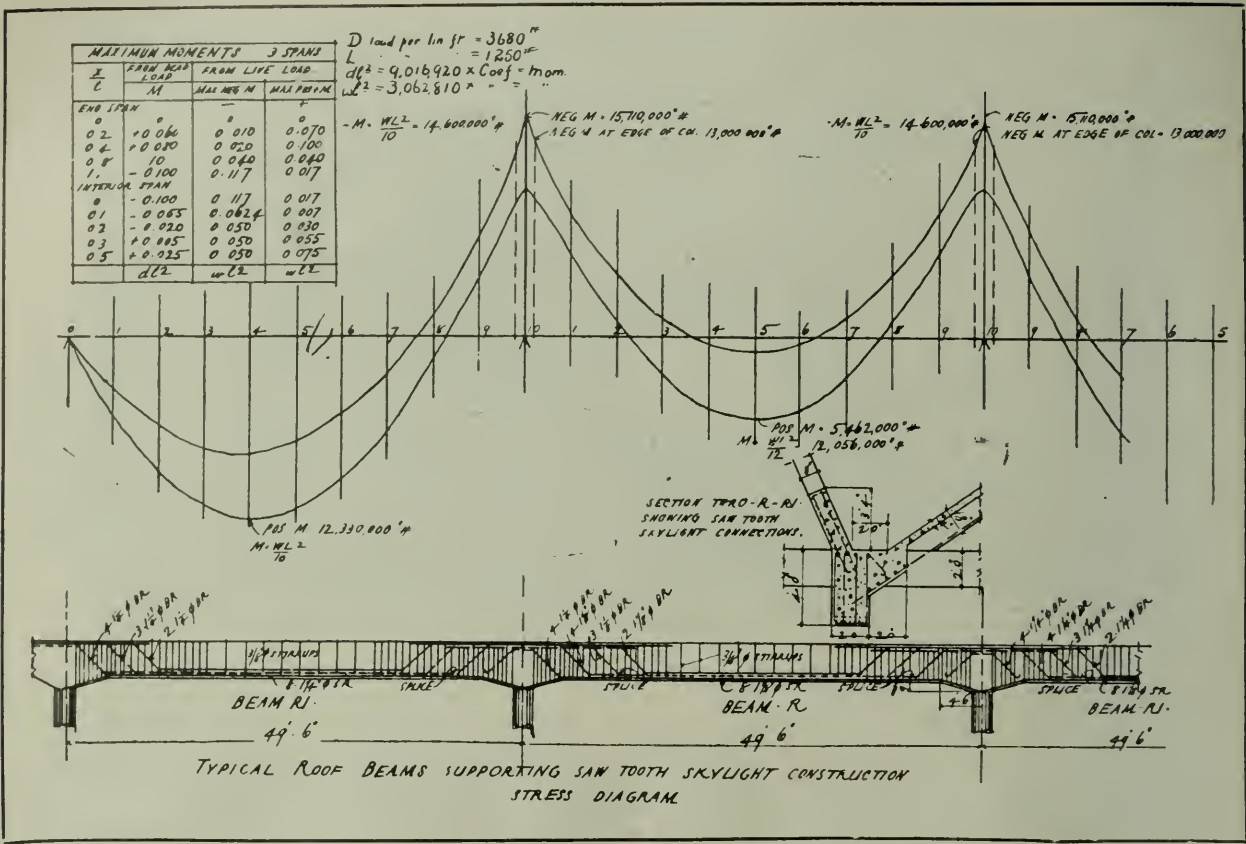
The 310 interior circular columns vary from 24 in. to 40 in. in diameter (those in the lower story being designed for live loads of 1,500,000 lb. each) and are reinforced with 26 1¼-in. vertical rods and $\frac{9}{16}$-in. spiral hooping. Duplicate loads were assumed for the columns in the two upper stories in order to secure uniformity in their design and in the steel reinforcement. The 68 exterior columns are from 21 in. to 33 in. square, and in the basement story were built integral with the exterior retaining walls on four sides of the building. All splices in the column verticals are made with 1½-in. U-bolts.

The general excavation, nearly 30 ft. deep, involved the removal of about 10,000 yds. of solid rock and 233,000 yds. of earth. Almost the first operation was the excavation by clamshell buckets and derricks of trenches 12 ft. wide that were dug to solid rock to receive the 3 ft. by 11-ft. concrete foundations of the retaining walls. The trenches were lined with 2-in. wooden sheet piles braced with cross struts that were removed as concrete was deposited in the forms constructed in the trenches.

The construction of the retaining walls in advance of other work permitted the interior excavation to be continuously maintained, and it was completed from one end of the building to the other, allowing construction work to go on before excavation was completed. Pits were excavated below the cellar bottom down to solid rock to receive the 7 ft. by 7 ft. concrete piers for the interior columns.

Concrete was delivered from the mixers to two wooden hoisting towers each of a height of 325 ft. Each tower was provided with a steel receiving hopper of 36-ft. capacity shifted to any elevation required for the distribution of concrete through chutes inclined about 1 : 3 and suspended from cables supported on the hoisting towers and on similar auxiliary towers of a lesser height. All the towers were guyed, and all were erected within the area of the building. The concrete was spouted to a maximum distance of 900 ft. through the main chutes and through branches from them that were supported on timber falsework set up on the finished floors wherever required.

The two mixers were operated by a force of 26 men and together delivered an average of 950 yds. of concrete daily. One-third of the building was completed in advance of the other, and the concrete plant was always operated so that the concrete was delivered as fast as it could be received and never caused any delay to carpenters, reinforcement gangs, or other workmen.



Reinforced Concrete Bottling Warehouse.

The great height of the basement story made it necessary to support the first-floor forms on an elaborate system of vertical shores braced with horizontal and diagonal struts. The beam and girder forms were carried directly on the caps resting on top of the shores and intermediately supported by knee-braces to the shores. The girder forms were made in the usual "knock-down" style with horizontal boards, and were left in position until the second or third story above them had been concreted. The bottom boards of the beam and girder forms remained longer in position with the vertical shores supporting them intermediately until several upper stories had been completed and the concrete was thoroughly set and safe to carry any load that might be imposed on it. The rectangular columns in the exterior walls were cast in forms built up from story to story and consisting of vertical planks enclosed in pairs of yokes. Each yoke was made with two transverse horizontal timbers and a pair of tension bolts with the ends of successive yokes in opposite directions overlapping each other. At the bottom of each form the yokes were placed as close together as possible, the intervals between them increasing in the upper part of the forms.

The forms for the high retaining walls were made of heavy horizontal boards with large outside vertical timbers set close together and connected by three tiers of rangers which were braced by inclined struts as the excavation progressed and the forms were filled.

The circular interior columns were concreted in sectional steel forms built up in position after the heavy reinforcement, assembled together to make single units for each column, had been placed in position.

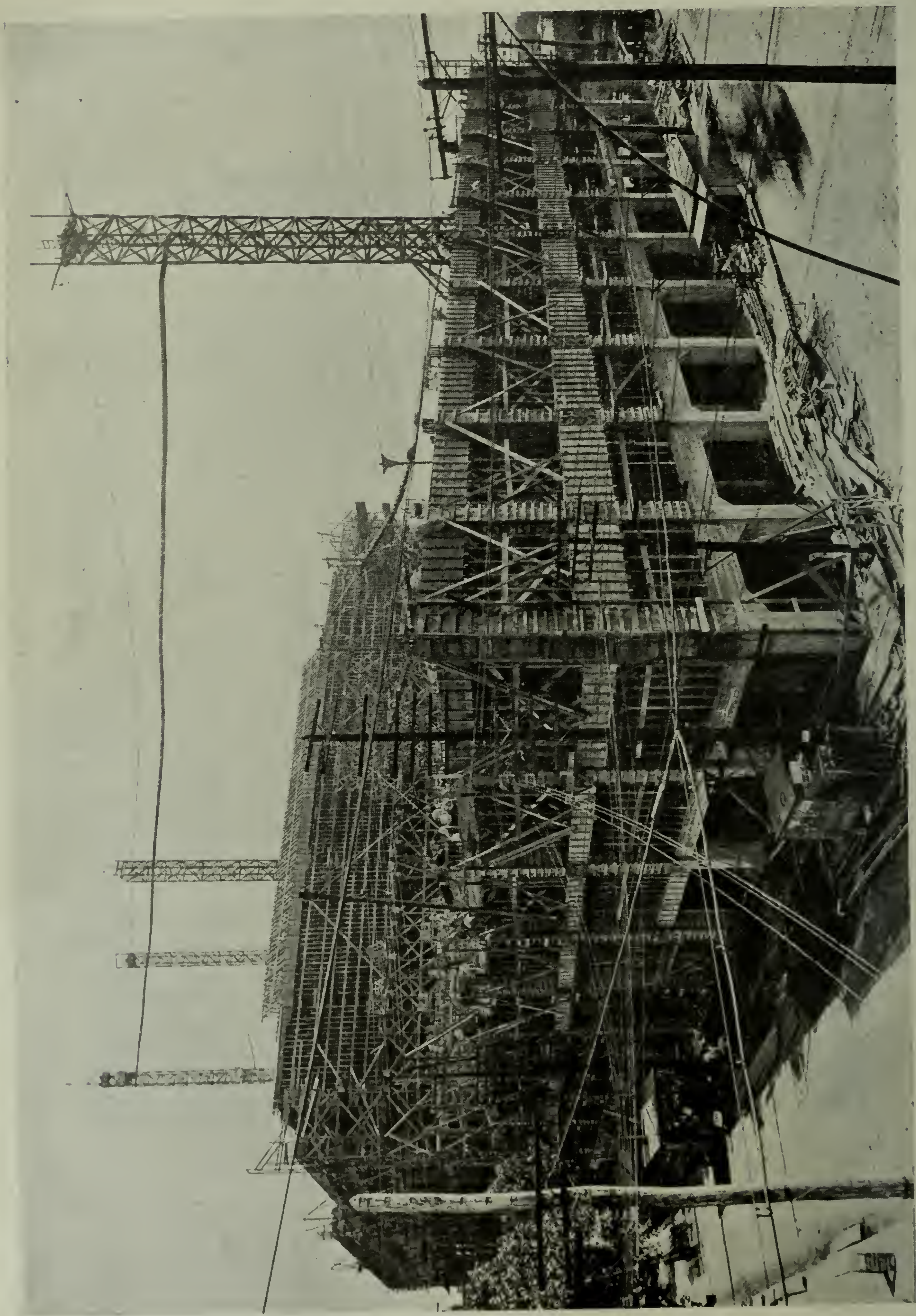
Particular attention was given to the accurate spacing and reliable support of the reinforcement bars in the forms, and every slab and beam bar in the building was supported in the forms and spaced to correspond with the engineer's design by supports and spacers.

The average number of men employed in the construction of the building was about 1,700. The quantities of materials included 121,560 bbl. of cement (making 81,040 yds. of concrete), 92,170 ½-in. U-bolts for splicing reinforcement bars, 80,000 inserts for ¾-in. bolts, and

REINFORCED CONCRETE BOTTLING BUILDING, ST. LOUIS. TOP STORY, SHOWING SAW TOOTH ROOF CONSTRUCTION.

5,951,200 ft. of lumber used in the construction of falsework and forms. The 8,780 tons of steel reinforcement was bent before delivery to the building. The building was completed within thirteen months from the commencement of operations.

The building was constructed by the Gilsonite Construction Co. Messrs. W. J. Knight & Co. and Mr. F. C. Taxis were associated engineers. Messrs. Widman & Walsh and Messrs. Klipstein & Rathman were associated architects.



REINFORCED CONCRETE BOTTLING BUILDING, ST. LOUIS: SHOWING FORMWORK. (*See p.* 781.)

EFFECT OF WATER CONTAINING SULPHATES ON CONCRETE.

THE effect on concrete of water containing sulphates in solution is a matter of great importance to engineers and builders, and the matter is by no means as well understood as it should be. The recent works of Strebel on the effect of water containing calcium sulphate (gypsum) and of Cary on the effect of peaty water are valuable, and the following abstract of a still more recent report by Dr. Herrmann (Director of the Charlottenburg Research Station) taken from *Tonindustrie Zeitung* adds still further to our knowledge of the subject.

A series of investigations on the effect of sulphates on concrete was started in 1916, with the following results :—

(1) Six different well-known brands of Portland cement were all unable to resist the prolonged action of a solution containing 10 per cent. of sodium sulphate, or of a similar solution containing magnesium sulphate. Five of these cements cracked after only five months, and were completely disintegrated in nineteen months. The more resistant cement, which lasted nineteen months before cracking, and was not completely destroyed in four years, contained only 5 per cent. of alumina, and only 61·8 per cent. of lime.

(2) Out of five first-class iron Portland cements similarly exposed only one was resistant for four years, and even this one showed signs of deterioration and could not be regarded as durable. In

REINFORCED CONCRETE BOTTLING BUILDING, ST. LOUIS: DURING CONSTRUCTION. (*See p.* 781.)

this case also the most resistant cement was low in lime (56·5 per cent.) and in alumina (8 per cent.).

(3) Two ordinary Portland cements made of slag, and two special slag cements, when mixed with sand and stored for two and a half years in a saturated solution of gypsum and a 10 per cent. solution of sodium sulphate respectively, showed no signs of deterioration, but were seriously affected in six months by a 10 per cent. solution of magnesium sulphate.

(4) Ore cements are made of iron ore and limestone in the same manner as Portland cements. They have the same composition as a Portland cement in which the greater part of the alumina is replaced by iron oxide. These ore cements, when mixed with sand, were more resistant, but in one case a lean (1 : 8) mixture immersed in a 10 per cent. magnesium sulphate solution was completely disintegrated in two months. On repeating the experiment with similar test-pieces, which were kept in water for forty-eight days before immersion in the salt solution, a wholly durable material was obtained.

(5) Two well-known Portland cements were mixed with trass and sand in the proportions :—

	A	B	C	D
Cement . .	1	1	1	1
Trass . .	0·7	0·7	0·5	0·5
Sand . .	3	8	2	8

These mixtures are all permanent in the gypsum and sodium sulphate solutions, but B was affected after two years by the magnesium sulphate solution.

(6) Mixtures of lime, trass, and sand in equal volumes are rapidly destroyed by all the salt solutions, and the use of double the proportion of trass effected no improvement.

The decomposition was due in each case to the formation of a crystalline calcium aluminium sulphate, which is formed when a soluble sulphate, free lime, alumina, and water are mixed together and allowed to stand. The crystals are stable in an alkaline solution, but on exposure to air they readily decompose, forming a slurry of calcium carbonate, sulphate, and alumina. When prepared synthetically they correspond to the formula $3CaO\ Al_2O_3,\ 3CaSO_4\ 24H_2O$.

The effect of this complex salt on concrete depends on the porosity of the latter and on the presence of sulphates in solution. With a limited amount of solution the pores in the cement become filled with the crystals of the calcium aluminium sulphate, and no further decomposition occurs, but if the conditions permit the removal of the crystals on the exposure of a fresh quantity of cement the decomposition continues. For instance, it may be observed in the concrete banks of some canals that the upper part of the concrete is completely converted to a whitish mass whilst the lower parts are unaltered, except superficially. The difference is almost wholly due to the mechanical effect of the " wash " of the more rapidly moving surface-water

The prevention of this destruction of concrete by sulphatic waters is difficult. It lies chiefly in making the concrete waterproof by the aid of a repellent, or the use of a rich mixture (such as 1 part of cement to 2 parts of sand), or by the addition of a little trass, as previously mentioned. Slag cements are also useful, but they should be specially made for this class of work.

If the sulphatic water is under pressure a rich ore cement mixture may be used. If a rich mixture of good Portland cement and sand is cured by immersion in soft water for several weeks before it is exposed to the salt solution a greater resistance to the latter will be obtained.

Attempts to insulate the concrete by coating it with a solution of asphalt or tar, in benzol, or other impermeable materials, have not proved satisfactory—chiefly because it is seldom practicable to obtain a sufficiently adherent coating.

REINFORCED CONCRETE AND FIRE-RESISTANCE.

IV. ACTION OF GRANITE UNDER HEAT TREATMENT.

By J. SINGLETON-GREEN, B.Sc. (Hons. Eng.), A.M.I..Struct.E., M.Am.C.I.

GRANITE.

STRICTLY speaking, granite is an acid plutonic igneous rock consisting of quartz, orthoclase, and mica. But the term granite was first applied vaguely to granular rocks in general, independently of their mineral composition or mode of origin; and commercially the name is still used in this broad sense, as the following examples show[1]:—

Commercial Name.	*Geological Name.*
Rowley Regis granite	Dolerite.
Teign Valley granite	Diabase
Nuneaton granite	Quartzite (also Diabase)
Ingleton granite	Conglomerate
Mendip granite	Limestone
Petit Granit (Belgium)	Limestone.

Dr. Arthur Holmes points out that none of these examples corresponds in composition, texture, or mode of occurrence with granite proper, and the common practice of misapplying the name in this way is one that should be carefully avoided; for otherwise, instead of describing a well-defined group of rocks, the name becomes meaningless, and liable to lead not only to confusion of thought but even to actual error in building and other specifications.

ACTION WHEN HEATED.

Since a large proportion of granite consists of silica it would be reasonable to expect its action under heat to be similar to that of silica, and this is in fact the case. As far back as 1880, Cutting[2] pointed out that a heat sufficient to melt lead (600 deg. F., or 316 deg. C.) was sufficient to injure granite walls beyond the capability of repair.

In 1906, McCourt[3] tested 3-in. cubes of eighteen samples of New York building stones for fire resistance, and the poor fire-resisting capacity of granite was very pronounced. At 850 deg. C. all the cubes tested were damaged, but to varying degrees. Coarse-grained granite suffered most severely by cracking around the mineral grains, while the fine-grain varieties were less subject to crumbling of this kind but were damaged by spalling at the corners.

Since granite is composed of three different minerals it is only natural to expect that there will be disintegration when it is heated, on account of the different coefficients of expansion of the quartz, felspar, and mica. As pointed out when discussing the expansion of quartz, the cubic expansion of quartz is twice that of felspar, and it can be easily seen that in a haphazard aggregate of these minerals very severe strains must be developed, resulting in powerful shearing and wedging action between adjacent grains.

As the temperature of granite increases its strength decreases, and in Tarr's investigations[4] it appears that the graph showing the relation between the compressive strength of granite and its temperature is almost a straight line. Two granites were specially tested at various temperatures up to 1,000 deg. C., and it was shown that the strength declined rapidly until at 800 deg. C. it was only a quarter of the original value. It is interesting to note that in four cases the specimens which were heated to 500 deg. C. and cooled in water were found to be stronger than those which had cooled in air, showing that sudden chilling by water is not necessarily an additional cause of weakness.

TESTS BY DAY, SOSMAN, AND HOSTETTER.

Probably the best information yet available relating to the expansion of granite is to be found in a paper published by Day, Sosman, and Hostetter in the *American Journal of Science*.[5]

Two granites were heated above 575 deg. C.:—

[1] B.F.P.C. No. 256, p. 37.
[2] *Weekly Underwriter*, Vol. 23, p. 42, 1880.
[3] Fire Tests of some New York Building Stones, W. E. McCourt, New York State Museum, Bulletin 100, 1906.
[4] Eng. Experiment Series, Bulletin 27, Vol. 15, University of Missouri.
[5] A. L. Day, R. B. Sosman, J. C. Hostetter in *American Journal of Science*, 4th Series, Vol. 37, 1914.

(1) A pink coarse-grained quartzose granite from Alaska.
(2) A gray biotite-muscovite granite from Georgia.

In both these granites the rapid volume increase on approaching 575 deg. C. is notable. This increase is to be expected from the presence of free quartz in the granite, but its amount is unexpectedly large. The volume increase of the two granites between 0 deg. and 575 deg. is 5·07 per cent. and 5·82 per cent. respectively, giving a mean of 5·45 per cent. The corresponding increase for pure quartz is 5·17 per cent.

The most probable cause of this abnormally large expansion is the action of the pure quartz crystals in pushing the other mineral fragments apart, increasing the apparent volume of the rock. Evidence for this explanation is seen in the curve giving the data of a second heating of the Alaska granite. In this series the volumes are all larger, although the curve is parallel to the first.

Beyond 575 deg. C. there is a considerable expansion accompanied by the escape of gases, but this is not of immediate interest as the danger point is at 575 deg. C.

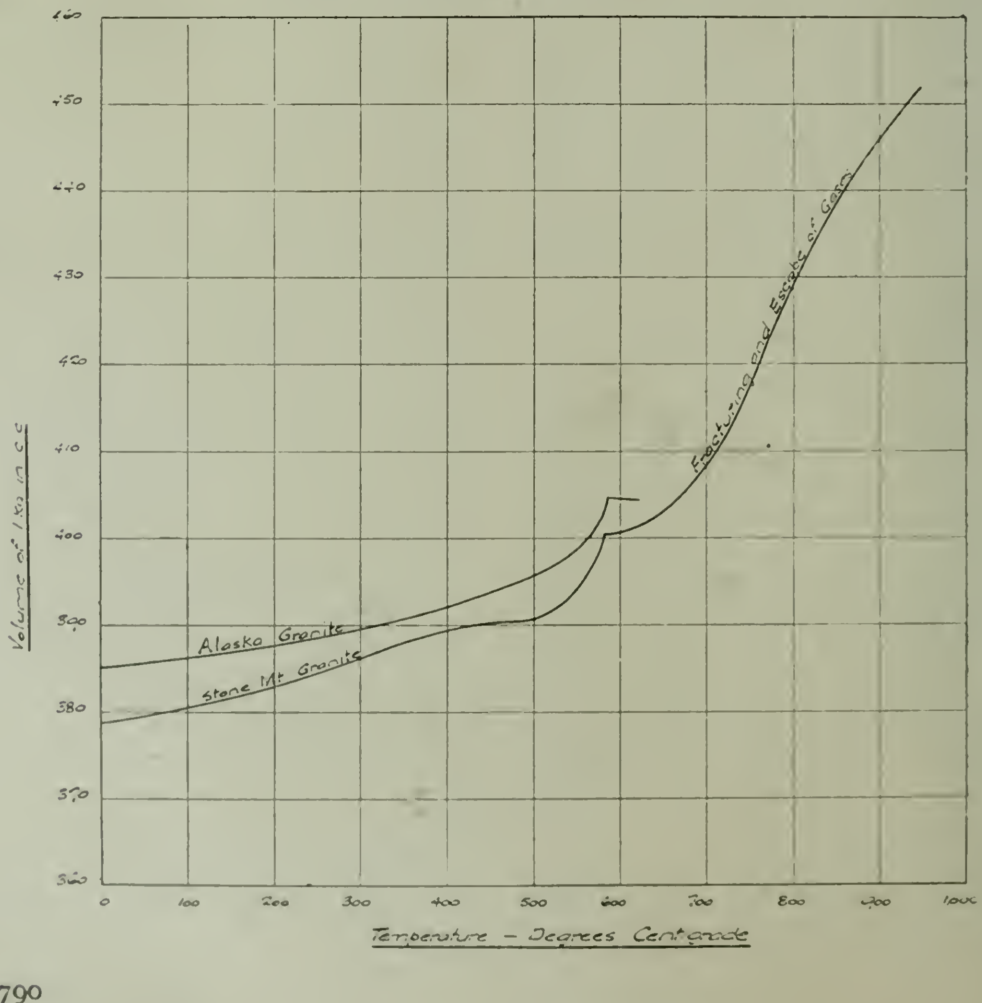
CONCLUSIONS.

From the foregoing evidence it is apparent that granite is not a suitable aggregate to use for reinforced concrete construction if a high degree of fire resistance is required. This is specially unfortunate since granite is one of the best of our aggregates from a structural point of view, and very often also from an economic point of view. Actual tests on granite concretes confirm this. For instance, the results of tests on natural aggregates carried out by the British Fire Prevention Committee are briefly [1] :—

[1] Paper by Mr. D. W. Wood, Junior Institution of Engineers Journal and Transactions, Vol. 31, Part 10, July, 1921.

EXPANSION OF GRANITE

(after Day, Sosman & Hostetter)



Temperature – Degrees Centigrade

1. Thames ballast, or any flinty aggregate, proved unsatisfactory from a fire-resistance standpoint.
2. Gravels and sandstones were also unsatisfactory.
3. Limestone showed somewhat better results.
4. Igneous rocks were generally poor, Nottingham basalt proving the best, with trachyte next.
5. Granite did not behave well.

SANDSTONE, DOLERITE, ETC.

The action of sandstone does not need special treatment since sandstone is composed mainly of silica, and the results can be readily surmised.

It is to be noted, however, that some of the igneous rocks, although far from perfect, behave much better than granite. The igneous rocks other than granite in general use are quartz-diorite, trachyte, basalt, dolerite, and diabase. In B.F.P.C. Red Book No. 256, Dr. Holmes points out that there is a certain amount of confusion between the names "dolerite" and "diabase." It is necessary to note that the term diabase is sometimes used, especially by the American authorities, in the same sense as dolerite is now used in this country, i.e., for the comparatively unaltered rocks.

English.	*Irish.*	*American.*
Dolerite	Dolerite.	Diabase.
Basalt.	Basalt.	Basalt.
Diabase.	Basaltic Andesite.	Altered Diabase.

Dolerite on heating does not behave like granite. Wheeler [1] found that on heating there was a gradual expansion to beyond 1,000 deg. C. and the coefficient of expansion appeared to be 25·2 by 10^{-6}. The expansion was much less than that of granite, and the permanent elongation was barely 0·7 per cent. Similar results were obtained by Day, Sosman, and Hostetter.

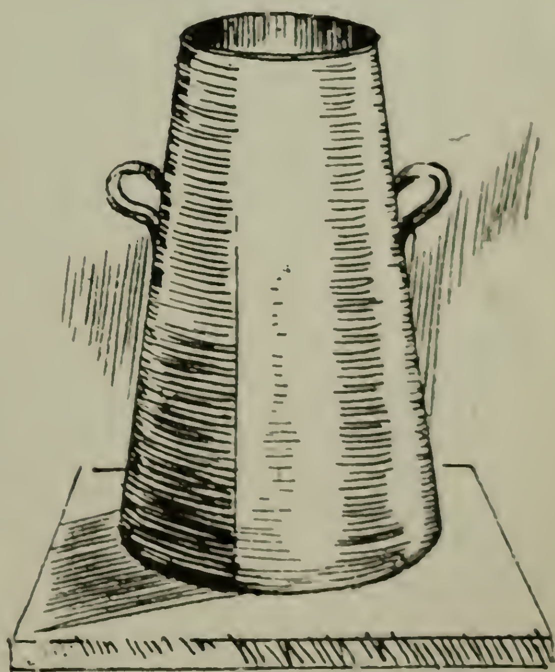
German fire tests on reinforced concrete houses were described in *Concrete and Constructional Engineering*, Vol. 15, Nos. 5, 6, and 7, 1920, and it was there pointed out that the tests demonstrated unequivocably the superiority of basalt over granite as an aggregate.

[1] Trans Roy. Soc. Canada, Ser. 3, Vol. 4, pp. 19-44. 1910.

THE SLUMP TEST FOR CONCRETE.

THE following is the usual method of applying the slump test for the consistency of concrete :—

The newly-mixed concrete is placed in a truncated cone-shaped metal mould 12 in. high, 8 in. diameter at the base, and 4 in. in diameter at the top, and provided with handles at the sides (see sketch). The concrete is lightly tamped with a rod as it is placed in the mould which, when filled, is immediately removed and the slump or settlement of the concrete noted. The test should be applied to a portion of the first batch of concrete that is mixed, and if the slump is not in accordance with the specification the quantity of water added to the next mix should be altered and the slump again measured, repeating the same procedure on the next batch if necessary. Having arrived at the correct consistency, the test should then be applied several times per day to ensure that the required consistency is uniformly maintained.



APPARATUS FOR DETERMINING THE CONSISTENCY OF CONCRETE.

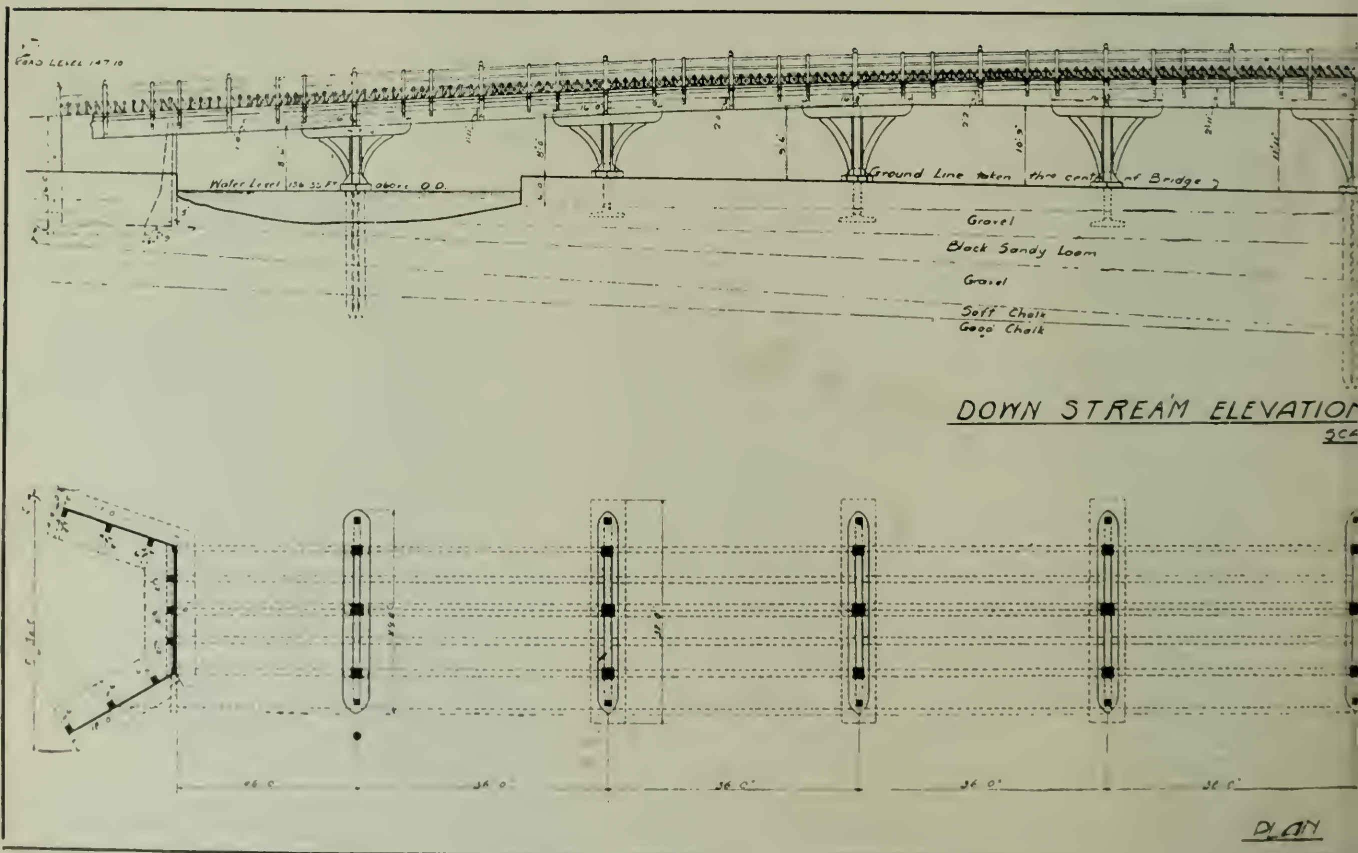
RAILWAY STRUCTURES IN CONCRETE.

Reinforced concrete has been extensively used on the Wurtemburg railways for the past fifteen years, and a recent official examination of these has given very interesting results.

All the reinforced concrete has stood well, the cracks which have formed being wholly superficial and of no importance. They are due solely to shrinkage of the material and to the effect of heat and weather, and are in all cases attributable to lack of sufficient provision for the effect of such forces when designing or executing the structures in which they occur. In no cases were deep or serious cracks found in the work carried out in reinforced concrete.

Mass concrete has proved less satisfactory, and cracks in it are more serious. Supporting walls, arches, bridges, and buttresses all show cracks, due to shrinkage of the concrete and not to the stresses imposed by the loads they have to carry or resist. Cracks are specially noticeable at the places where one day's work ends and another begins, some of these cracks being $\frac{1}{12}$ in. wide. They are particularly noticeable where the sun's rays fall directly on the concrete, and are seldom seen on parts which have been kept constantly moist. The most serious cracks are on covering plates, thin walls, and walls of mass concrete. Most of the cracks appeared soon after the shuttering had been removed, and the sun and wind had access to the concrete and caused it to dry out too rapidly. Some cements behave very differently from others in this respect, and in some concretes no shrinkage cracks appear in the first five years. It is now certain that fresh concrete should not be left exposed to the sun and wind without protection; it should be kept wet for a sufficient length of time to prevent shrinkage cracks from appearing. In some cases, the concrete blocks or slabs should be made in a factory, properly cured, and then built into the desired position.

In independent walls there should be expansion joints every 5 or 10 yds., whilst



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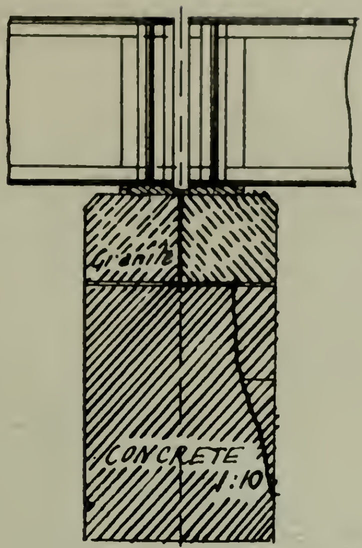
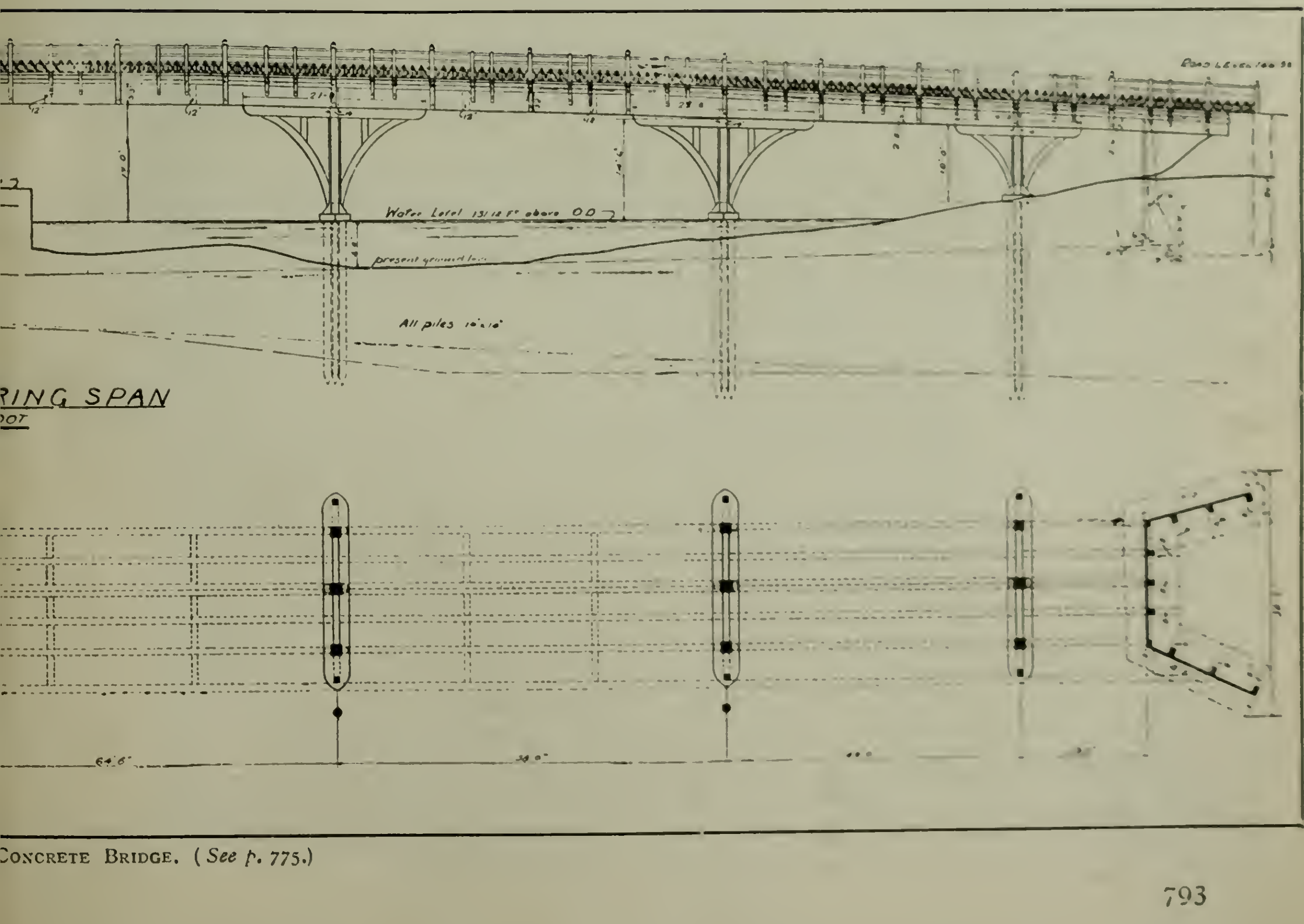


CRACK IN PIER OF CONCRETE BRIDGE.

walls which are used as supports for earth or other materials and filled-in walls should have such joints at least every 10 yds. Only when reinforced concrete is used can the space between the joints be 40 yds., and even then only in favourable cases. Greater care should be taken in making such joints, and they should be examined occasionally as they tend to open unduly.

In building railway arches it is necessary to allow a certain amount of " play " to counterbalance the sinking of the centre of the span. Experience has shown that the allowances usually made are not sufficient.

Flat bridges built of mass concrete sometimes crack vertically in the end piers as a result of the expansion and contraction of the roadway, particularly if the latter is laid on iron and the pillars are of mass concrete. In one bridge the platform was designed to be in one piece but was actually built in two, the ends of each meeting above a concrete pier; the latter was badly cracked for a distance of over 5 ft. vertically, the crack being nearly $\frac{1}{2}$ in. wide (see *Fig.*). It is essential that sufficient care should be taken to allow for the forces developed on the bearing plates by the movement of the platforms of bridges, as well as for the direct load on the piers.—*Beton ú Eisen.*



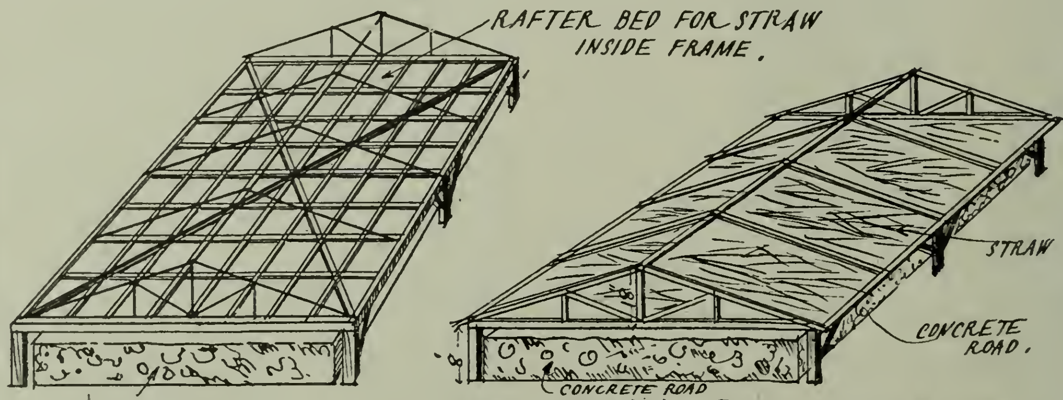
CONCRETE BRIDGE. (*See p.* 775.)

PROTECTION OF CONCRETE ROADS FROM FROST.

We have received the following from Mr. Del Tonkin, Inspector of Concrete Roads, of Market Drayton :—

"To protect newly-laid concrete roads from frost is the anxiety of every concrete engineer. The accompanying sketch of a frost and rain protecting frame is my own design and has been used with success.

"The frame is constructed according to the width of concrete road, allowing 2 in. on each side of the shuttering for easy placing and removing. Assuming the



SADDLE BACK ROOF FRAME FOR TARPAULINS WITH STRAW INSIDE ON RAFTER BED.

road to be 20 ft. wide with shuttering 6 in. by 2 in., the frame would be made 20 ft. 8 in. wide and 8 in. deep at the sides, to bring the straw bed as close to the concrete as possible without touching it, say, within 2 in. The fall of the frame roof should be 18 in. from the centre, which would allow an easy fall for rain. When placed in position, filled with straw, and covered with waterproof tarpaulins, it is probably the best frost and rain protector. To test the temperatures, I placed two thermometers of the same make one inside the frame and one exposed outside. The thermometer outside registered 32° F., or, freezing point, while that inside registered 46° F. The tarpaulins must overlap the sides and ends of the frame to prevent any current of air passing through. If sufficient of these frames with straw and sound waterproof tarpaulins are placed over a newly-constructed length of road, the mind of the concrete engineer can be at rest when the thermometer registers 'Frost.' Since writing the above I have again tested the frames (November 24), and found that whilst the outside temperature was 26 deg. F., a thermometer inside registered 42 deg. F."

The Wear of Concrete Road Surfaces.

A concrete road at Pittsburg has been subjected to exhaustive tests under the supervision of the U.S. Bureau of Standards by the operation of an average of thirty fully-loaded 3½-ton and 5-ton trucks. The tests are to be continued, but some interesting interim results are published. It has been found, for instance, that a 6-in. concrete slab, after deflecting under the weight of a 5-ton truck, does not recover its former position for more than two hours, and that after being subjected to traffic for a longer period, the rate of return is somewhat slower, due probably to fatigue of the materials. In the tests the trucks have travelled a distance of 96,000 miles, and it has been ascertained that after carrying 3,500,000 tons of traffic on solid rubber tyres, the surfaces of the road show no sign of abrasion. Marks of the finishing tool on the concrete are still visible, as also are the paint marks with which the road was laid out in squares. It is estimated that the traffic which has passed over this experimental road without injuring it is equivalent to the amount of traffic which could be expected on a Californian road during a period of from twenty-five to forty years.

RESILIENT CHAIRS AND FERRO-CONCRETE SLEEPERS.

THE GREEN-MOORE SYSTEM.

It has been the habit of engineers to designate rail supports as chairs and sleepers, the chair being the metal holder for the rail and the sleeper being the timber baulk to which the chair is fastened, and this definition has generally been maintained by those who have endeavoured to find a substitute for one of the materials employed while still retaining the other. There can be no doubt that this endeavour to follow an existing practice while substituting a totally different material has caused failure after failure and many disappointments; in the Green-Moore system illustrated herewith, however, the subject has been approached from an absolutely independent point of view, namely, as a rail support formed of a suitable combination of materials.

In order to do this completely a number of phases in connection with the chair and sleeper must be considered, so as to adapt one's ideas to the conditions obtaining when the different materials are used. The first points for consideration are whether the cast-iron chair is the most suitable form of attachment between a rail and a foundation so totally different from a baulk of timber as is a concrete block—whether the rail carrier must of necessity rigidly support both rails as do timber sleepers. Before this latter point can be settled the effect of dividing the base into two parts must be analysed. To do this the stresses which occur in a wooden sleeper 9 ft. long by 10 in. by 5 in. with chairs 14 in. by 7 in. fixed 5 ft. centre to centre must be carefully estimated. This sleeper is packed with ballast of varying qualities and with varying skill, and if the sleeper is correctly packed its bearing will be about 1 ft. on each side of the centre line of the rail.

Green-Moore Reinforced Concrete Sleepers.

leaving an unpacked space on the centre line of the track. In this case there is no vertical bending moment in the centre of the sleeper, but if, as is frequently the case, the whole length of the sleeper is bearing, and the packing at the end of the sleeper where the greater weight occurs is not thoroughly maintained, a vertical bending moment is introduced in the centre of the sleeper, and, as the moments of resistance of a sleeper are trifling compared with the bending moment due to an axle load of 18 tons, the sleeper must bend until the outer ends get a hard bearing. This bending will go on increasing as long as the road remains in an insufficiently packed condition. The result of this bending is that the curve of the sleeper increases the gauge, with the result that on the sleeper immediately ahead of the advancing weight the twist induced in the rails tends to draw or slacken the hold-downs of the chair to the wooden sleeper, and also to slacken the key. This is one of the causes of deterioration of the attachments of the chair to the timber, and also reduces the grip of the rail in the chair and facilitates creep.

Another question which must also be carefully considered is that by dividing the rail carrier support into two parts the horizontal moments of resistance are eliminated. The horizontal moments of resistance in the timber baulk are often regarded as holding the rail lengths in their relative positions to one another transversely, and preventing creep. This would be the case if it were not for the effect of the vertical bending moment, as before described, lessening the grip of the rail in the chair so that although the sleeper may remain in its true position the rail creeps in the chair.

Now, if the rail carrier is divided into two complete items, bonded together by a tie rod having neither vertical nor horizontal moments of resistance, each rail carrier can be designed to do its own work without distorting or distressing the other. To do this, sufficient bearing area must be provided in each rail support, equally distributed around the centre of pressure. Each bearer must be so shaped as to produce, in combination with its load and weight, sufficient resistance to being drawn laterally through the ballasting ; further, the method of connecting the rail to the chair should be such that the weight of a passing train will always tend to make the grip of the

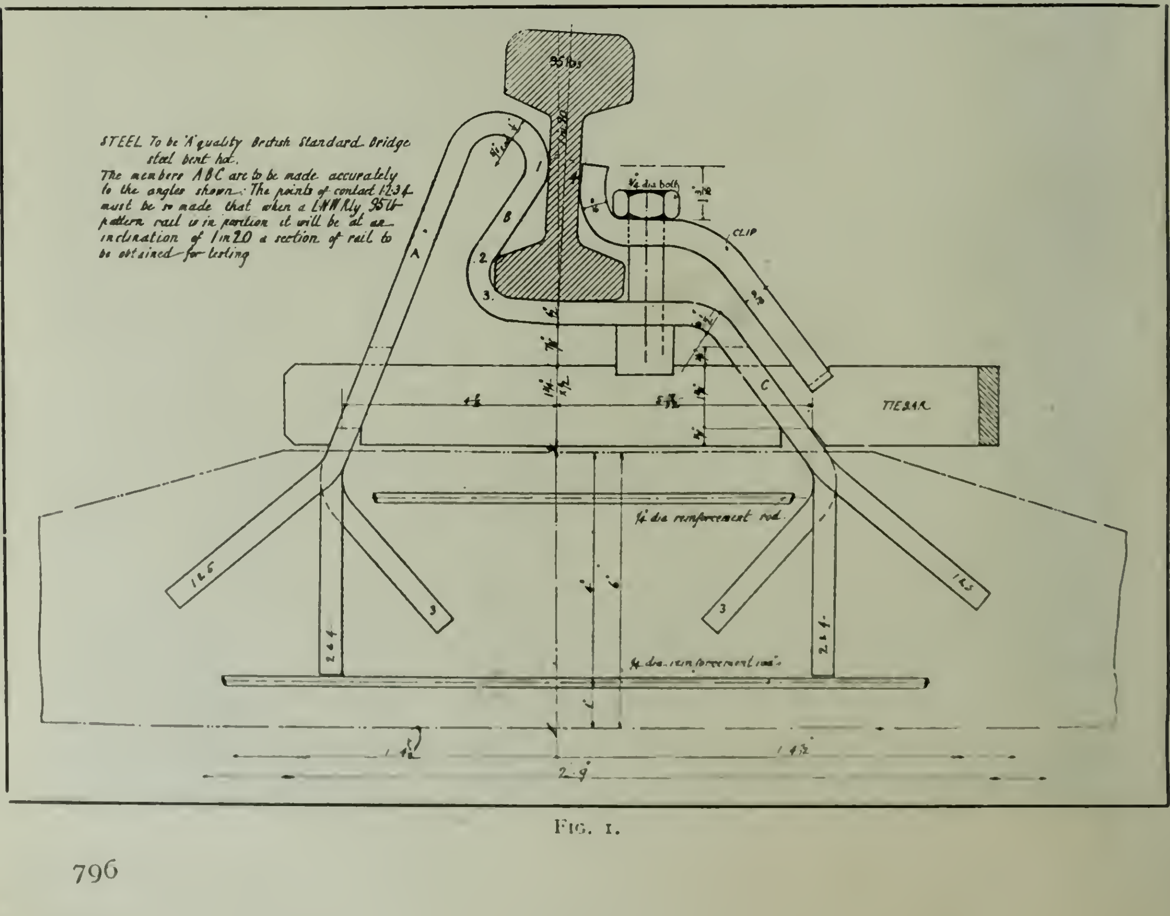


FIG. 1.

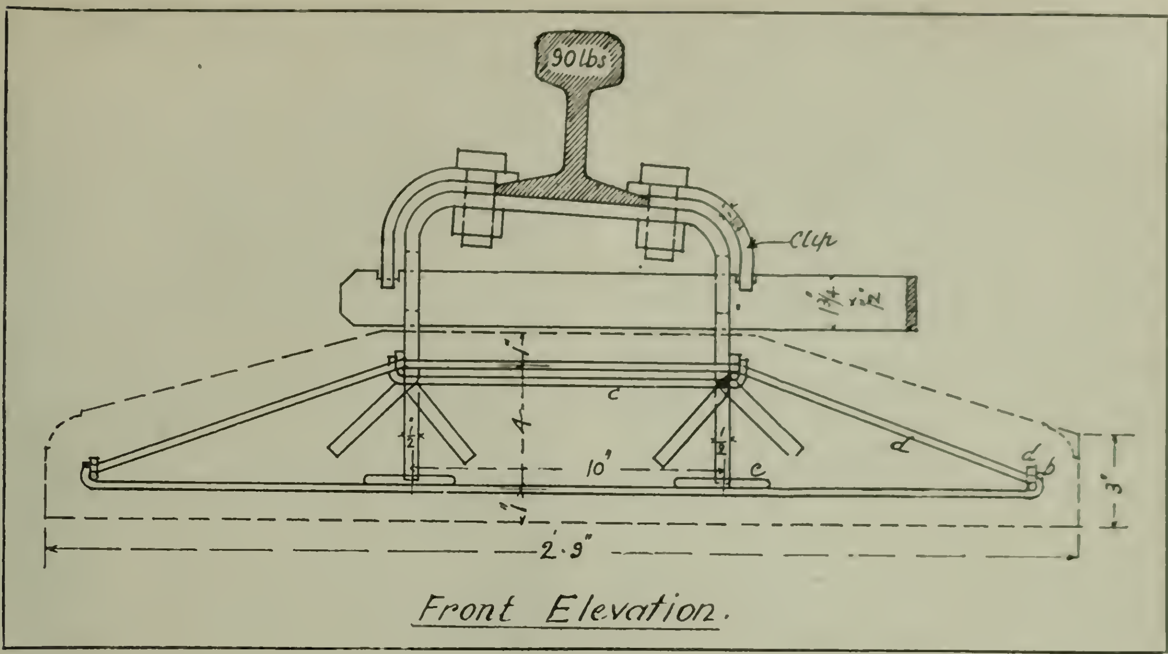


Fig. 2.

chair to the rail greater, so that the resistance to creep shall be the resistance of the face of each rail support against the ballast on the whole length of the track, not only, as is frequently the case with timber sleepers, the resistance of those at the end of each rail.

On this question of the necessity for vertical and horizontal moments of resistance in the sleeper, opinion varies according to the nature of the experience of the engineer. In England, where the divided sleeper is practically unknown and the engineer has little opportunity of experimenting with it and studying it, it is not liked ; whereas in India, where the divided sleeper occurs in many forms (such as the D & O plate sleeper) they are taken for granted and put in roads for high-speed trains with 18-ton axle loads.

The divided form is undoubtedly the most suitable for a ferro-concrete sleeper. We therefore come to the question of how the rail should be attached to the concrete base, and with what material. When a cast-iron chair is fixed on a wooden base the wooden base contributes a certain amount of resilience to the combination, but a cast-iron chair on a concrete block is practically devoid of resilience. In the Green-Moore combination the solution to this problem is obtained by a resilient connection between the rail and the concrete block, as shown in *Fig.* 1 for bull-headed rails and *Fig.* 2 for flat-footed rails.

The success of the Green-Moore type of sleeper in operation on the Indian Railways is shown by the following extracts from reports of the Senior Government Inspector for the years 1915–16 to 1919 :—

Report for the year 1915–16.—The Green-Moore reinforced concrete sleeper has stood a year's trial on the Down line between Howrah and Burdwan without any sign of failure. The sleeper is on the principle of the D. & O. plate, *i.e.*, in two halves tied with a tie-bar. The bearing area on the ballast is about 25 per cent. greater than that of the D. & O. plate. This sleeper is easier to handle than any other pattern I have seen ; the total weight of a sleeper is 400 lb., of which one-half only requires to be lifted bodily for laying purposes at a time.

Report for the year 1916–17.—The Green-Moore reinforced concrete sleepers referred to in paragraph 5 of last year's report were examined and found to have stood another year's heavy traffic very well. A vibrating table has been received for making these sleepers. When the first cost, and probable life, are taken into account, it looks as if these sleepers would drive wooden and metal sleepers out of the market ; all the materials of which they are made can now be supplied in India.

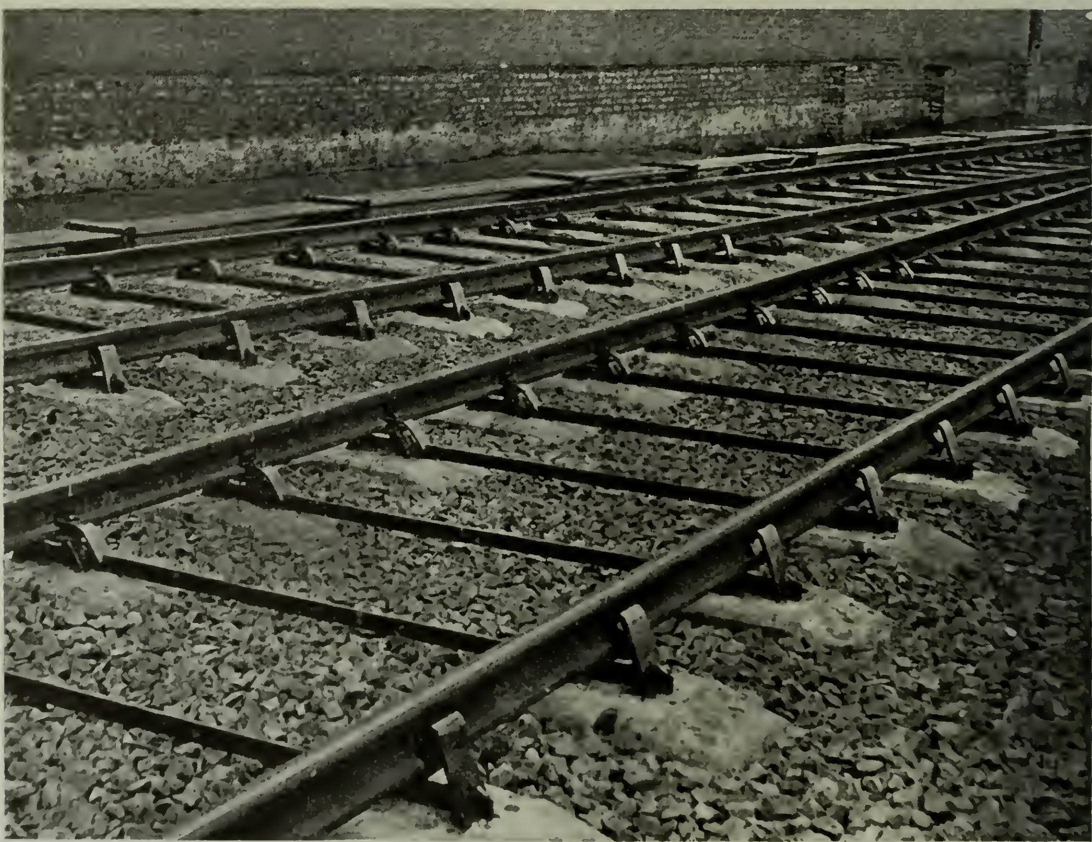
Report for the year 1917–18.—The (Green-Moore) reinforced concrete sleepers mentioned in the last two reports were examined. From their appearance at present they seem likely to have a long life in front of them; there is no perceptible shaking of the rail support where embedded in the concrete, and the undersurface of the sleeper has not been unduly chipped off from packing.

Report for year ending March 31, 1919.—The (Green-Moore) reinforced concrete sleepers mentioned in the last year's report are still in perfect condition. Their pre-war price, everything included, worked out to Rs. 7.0.0. only. No signs of weakness are as yet apparent in the concrete plate owing to shaking of the rail support.

Some of these sleepers have now been in the road for nearly five years, and their present condition fully warrants the assumption of a working life of at least twenty-one years for them under main line conditions.

The East India Railway has now nearly completed building works capable of manufacturing fifty thousand Green-Moore sleepers for bull-headed rails per annum and capable of being extended to manufacture one hundred thousand per annum. The Bengal Nagpur Railway has taken out a licence to manufacture three hundred thousand of them for flat-footed rails.

The cost of these sleepers manufactured in England in large quantities cannot yet be definitely stated, but it is believed that taking their life into consideration, they will compare very favourably as to price with timber sleepers. The patent rights of the Green-Moore sleeper are held by Mr. Louis Green, M.Inst.C.E., and Mr. R. St. George Moore, M.Inst.C.E., of 91, Victoria-street, S.W.1.



Green-Moore Reinforced Concrete Sleepers.

CONCRETE FARM BUILDINGS ON LORD ASTOR'S ESTATE.

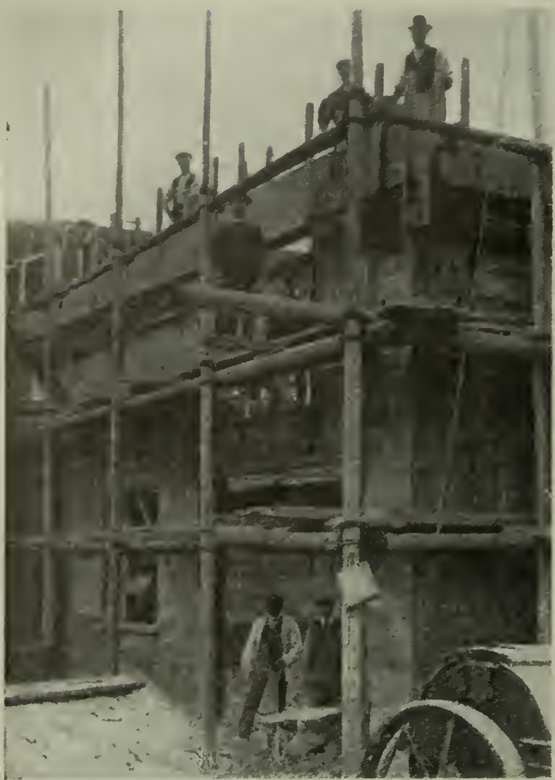
The cow-barn and food store illustrated herewith have recently been erected on Lord Astor's farm at Cookham, Berks.

The cow-barn is built with concrete walls, iron casements, and double doors allowing sufficient room for a cart to pass through the building to permit the collection of the manure. The floor consists of concrete, with oak blocks let in for sleeping. The mangers are constructed of concrete. The water mangers consist of brown glaze channels fixed transversely to the food mangers, and are fitted up to provide an automatic supply. The cows stand back to back, twenty on each side, and food carriers are fitted on an overhead track along the alley at the head of the cows.

The food store is fitted with oil engine, chaff-cutter, pulper, and grinding mill, all on the ground floor. The first floor is constructed for the storage of corn and cake, and the weight carried is approximately 5 cwt. per ft. super., the walls being solid. At the rear of the store is a cottage constructed of hollow walls, and a concrete calf-house has also been erected.

The buildings were constructed by Messrs. J. K. Cooper & Sons, Ltd., of Castle Hill, Maidenhead, with the use of a patented method of shuttering which, it is claimed, effects a saving of 25 per cent. compared with brickwork, and has also been used in the erection of cottages under the Government housing scheme. By this system of shuttering walls are built *in situ* of concrete slabs, or blocks of any desired size or shape. In the drawings on p. 801 it will be seen that two flat and parallel slabs (*a*) are formed to constitute a cavity wall, use being made of a plurality of transverse bearing irons (*b*) along which are disposed, one at each side, the outside shuttering boards (*c*). Parallel thereto are two inner shuttering boards (*d*), spaced apart according to the requirements and resting upon wall ties (*Fig.* 2). On the exterior of the outside shutters are erected vertical ledger members (*e*), a pair on each bearing iron, and the latter are at their extremities upwardly angled to embrace the ledgers (*e*). These ledgers are furnished with apertures at or near the top so that they may be braced in pairs by bolts (*f*), passing through parallel to the bearing irons. The bolts are tightened up against transverse horizontal struts (*g*) lying between each pair of ledgers under the

Concrete Cow-Barn on Lord Astor's Farm, Cookham, Berks.



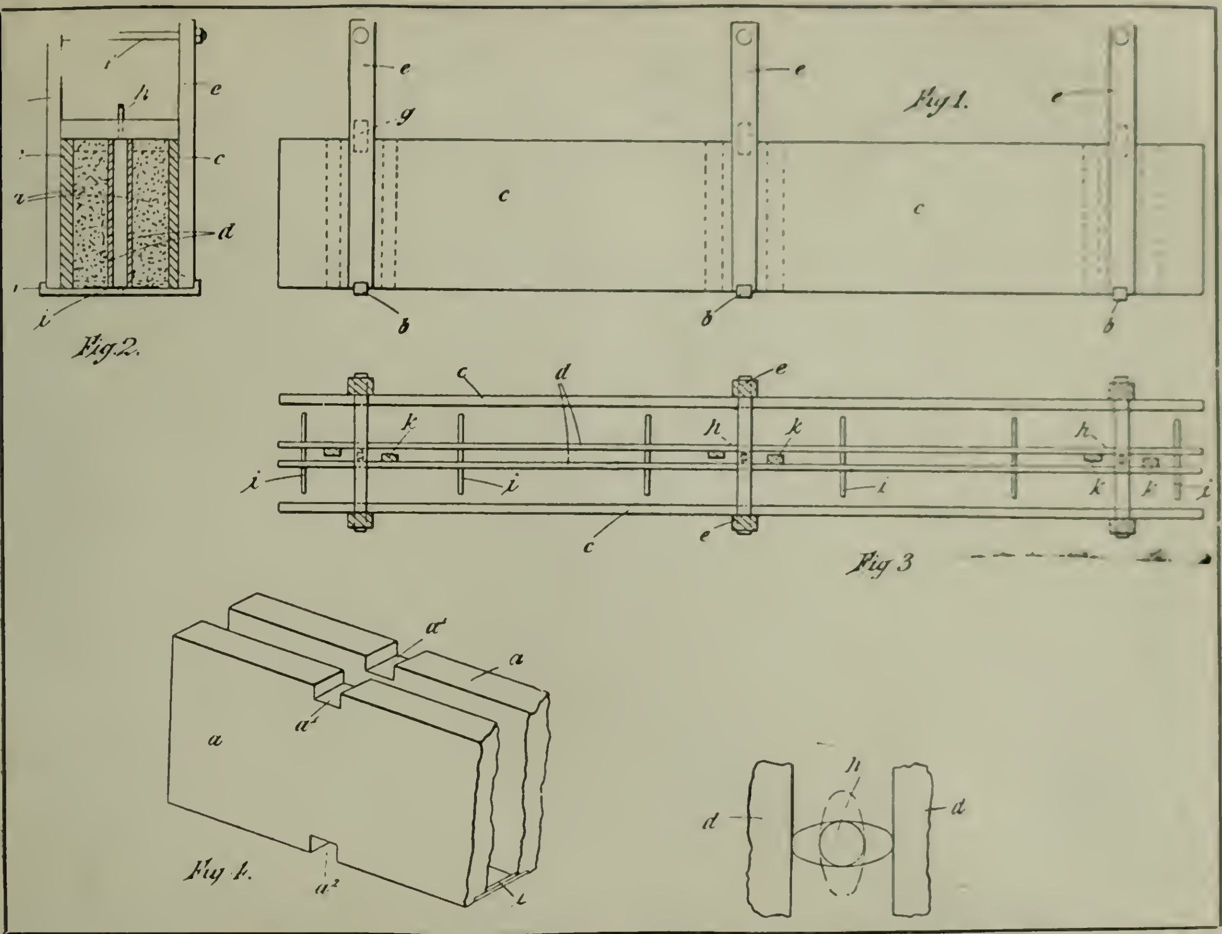
Food Store on Lord Astor's Farm, Cookham, Berks : During Construction.

bolts (f) respectively, the struts being recessed centrally and at their extremities to fit over the outer and inner shutters. This leaves and determines spaces for the concrete of which the slabs are formed between the shutters, and also spaces (a^1) in the slabs for the next row of bearing bars to be placed in position for a further row of shuttering to form another tier of slabs resting on the top of the first row.

The recessing of the struts leaves one (for solid walls) or two (for cavity walls) downwardly projecting pieces which dip into the concrete below the level of the tops of the shutters, thereby forming the spaces (a^1). Through each strut is passed a vertical rod (h)—with a square end to the top, circular section where passing through the strut, and oval from the bottom of the strut—passing between the two inner shutters to the bearing iron and thence through an aperture by a round extremity. By applying a key to the square end of the vertical rod and giving the latter half a turn the shuttering can be either fixed in, or released from, the cavity.

Fig. 4 is a perspective view of part of the slabs constituting a cavity wall, showing the spaces (a^1) for the bearing irons to support the next higher tier of slabs. The space (a^2) at the bottom of the slab is for withdrawing the bearing iron after the slab has been cast, and is formed in the concrete by placing sand along the top of the bearing bar before putting in the concrete. After casting the slab the bearing bar is pulled out with the sand, and the space left filled up with

Concrete Cow-Barn on Lord Astor's Farm, Cookham, Berks : Interior.



CONCRETE FARM BUILDINGS ON LORD ASTOR'S FARM, COOKHAM, BERKS: DETAILS OF SHUTTERING.

concrete. For the purpose of easy removal after casting the slabs, each bearing iron may alternatively be made with screwed ends instead of turned-up ends and be fitted with washer plates and nuts on the removal of which the bearing iron can be withdrawn from the slab.

The two parallel slabs are tied at convenient intervals by wall-ties (*i*) placed across the cavity at the bottom of the slabs before the concrete is put in, and the inner shutters rest upon the wall ties and are also stiffened with vertical battens (*k*) shown in *Fig.* 3.

QUESTIONS AND ANSWERS RELATING TO CONCRETE.

POLISH FOR CONCRETE SURFACES.

QUESTION.—Can you inform me how a concrete surface may be polished?

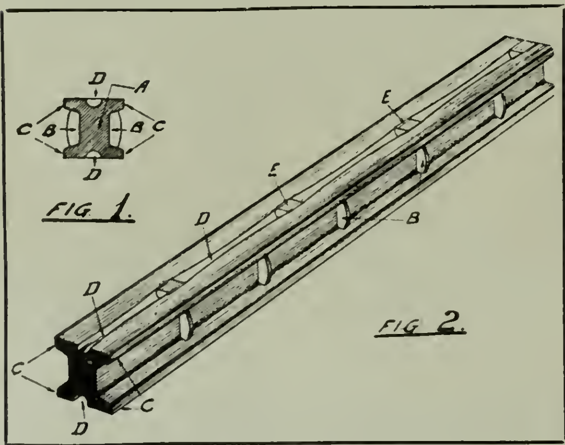
ANSWER.—In order to polish concrete like marble or granite the surface will have to be rubbed down as in terazzo work. A semi-polish can, however, be obtained as follows, supposing the surface to be reasonably smooth:—Dissolve ¼ lb. potassium carbonate in one quart of boiling water, and, whilst boiling, add and stir until dissolved, ¼ lb. of beeswax in slices; or melt the wax and add to the hot water and potassium carbonate mixture. If too thick, add enough hot water to make it creamy when cold. Apply with a brush or rag, let it dry or partially dry, and polish with a stiff brush.

RECENT PATENT APPLICATIONS.[1]

REINFORCING BARS.

[No. 177,684.—G. Jackson, "The Cedars," Albert Road, Wolverhampton, and W. W. Hickman, "Beech Tree House," Wall Heath, near Dudley, Staffordshire. March 7, 1921.]

This bar is formed so that the cross-section is of the **I** or girder section, as shown at A in *Fig.* 1, the object being to provide a maximum amount of surface with a minimum weight of bar; the ribs or projections (B) are formed between the flanges (C) at any required distance apart and of any required thickness, and of any required height or depth. The grooves (D) are formed in the top and bottom of the flanges (C), and at any required distance apart the ribs (E) are formed therein. The ribs (E) may be of



No. 177,684. Reinforcing Bars.

any required weight or thickness. The grooves (D) are shaped so that the width of each groove between the ribs (E) varies; that is to say, the extreme edges of each groove are not parallel with each other but are closer together in the middle of the space between the ribs (E) than at either end of the same space, thereby giving the whole groove (D) a wavy appearance. There may be one or more waves, as described, between each of the ribs (E). The object of the ribs or projections (E and B) is to form a mechanical bond, and the object of the waviness is to cause a mechanical bond independent of the mechanical bond formed by the ribs (E and B).

[1] These articles are prepared by Messrs. Andrews & Beaumont, Patent Agents, 204–206, Bank Chambers, 29, Southampton Buildings, W.C.2.

BLOCK MAKING MACHINES.

[No. 177,814.—E. C. R. Marks, 56 and 57, Lincolns Inn Fields London, W.C.2. (Communicated by Léan Co., Sweden). September 23, 1920.]

This invention comprises an improved machine for making blocks of the type in which the block is compressed into a moulding frame under the repeated blows of a vertically-movable ram provided with means for limiting its downward motion, the bottom of the moulding frame being meanwhile closed by a loose pallet placed on a fixed table, after which the pallet and the compressed block are released by raising the moulding frame, which is movable in an approximately vertical direction.

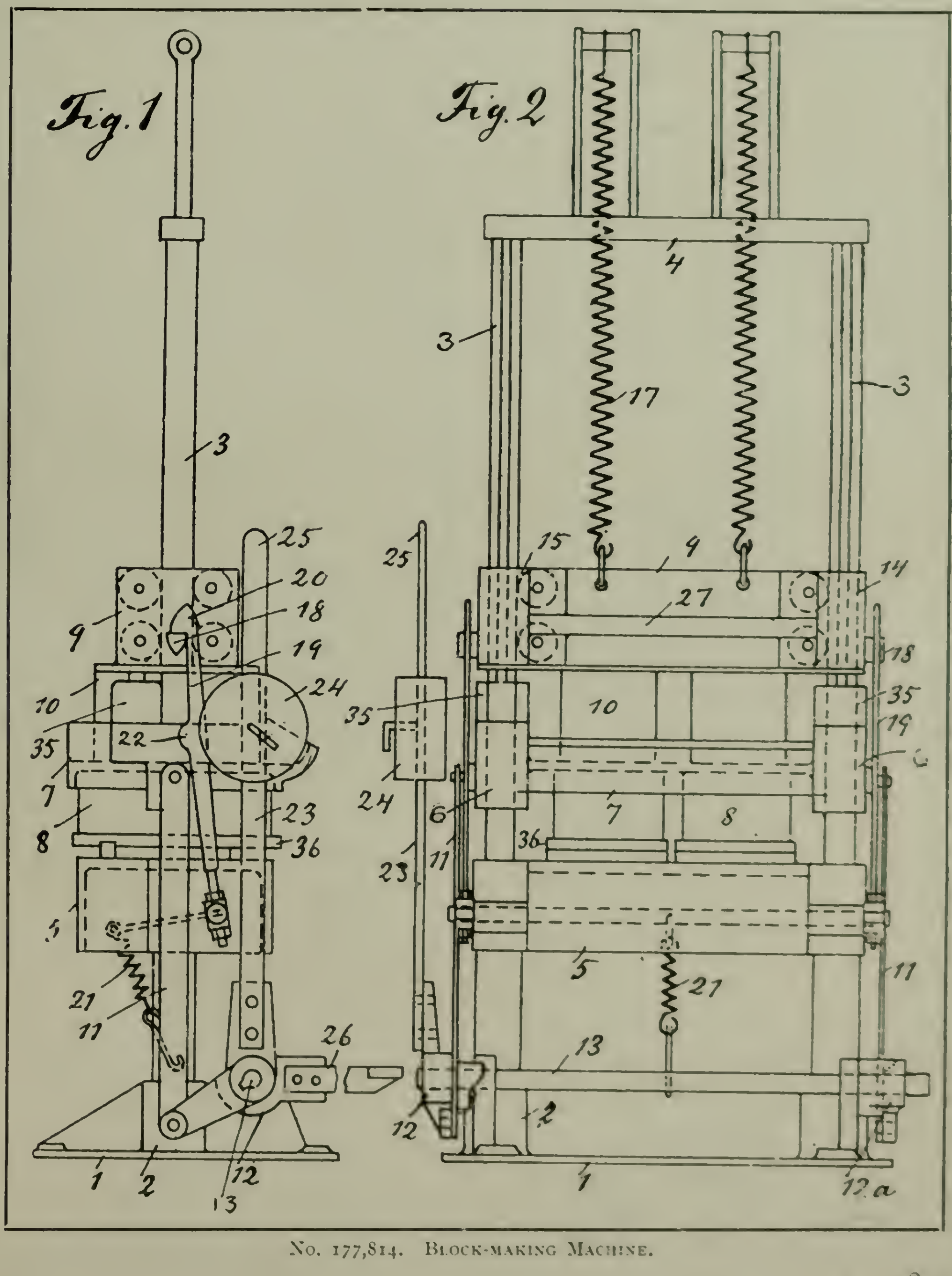
The improved machine consists of base plate (1) with sockets (2) for two vertical shafts or uprights (3) held together at their upper ends by a crosspiece (4). The fixed table or anvil (5) is firmly fixed to the shafts (3) which pass through guides (6) in a frame (7) carrying the female guide or mould (8), into which the concrete is fed, and through guides (14) of a tamping head (9), to which the male or upper die or mould (10) is attached. The frame (7) is held by two braces (11) connected to levers or links (12 and 12*a*) on a horizontal bottom shaft (13). In each of the guides (14) of the tamping head (9) there are journalled three pairs of rollers (15), two pairs of which engage the front and rear sides respectively of the shafts (3), while the third pair of rollers acts against the inner side of the shaft. The tamping head is suspended on springs (17) and provided with a horizontal handle (27) for lowering it. At each end of the tamping head there is a finger (18) for the purpose set forth below. On each side of the anvil (5) there is pivoted a lever (19), the upper end of which is formed into a hook or catch (20) intended to engage with the corresponding finger (18) on the tamping head. These levers (19) are firmly fixed to a horizontal shaft and actuated by springs (21) tending to keep them in engagement with the pegs (18). The levers (19) are each provided with a cam (22) against which the brace (11) strikes in rising, whereby the lever is disengaged from the finger (18). An arm (23) with counterweight (24) and handle (25) is attached to the bottom shaft (13), and a pedal (26) is firmly attached to the shaft or pivoted to it and engaging the arm (23).

CONCRETE MIXERS.

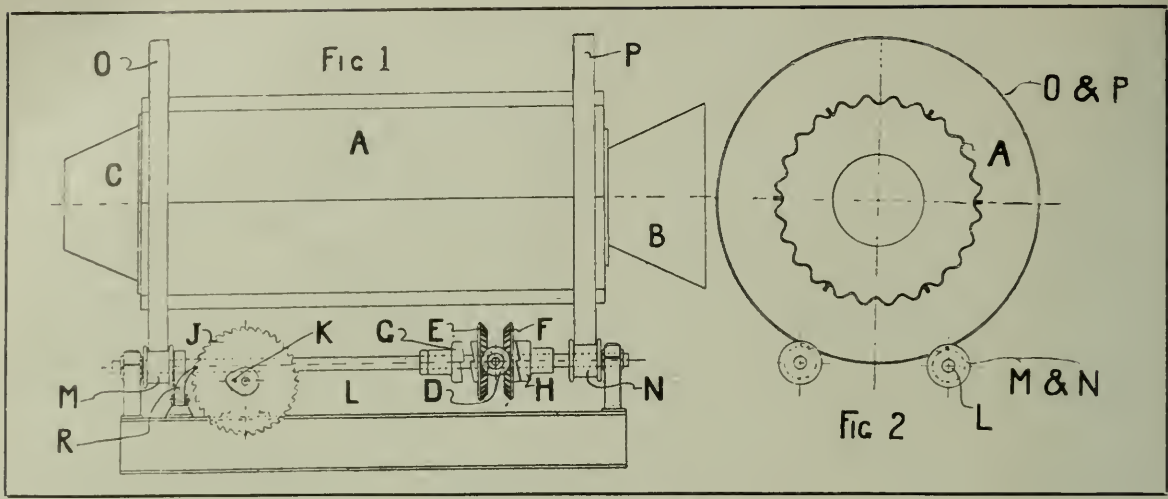
[No. 177,977.—J. Southall, Worcester Foundry, Worcester. March 16, 1921.]

A concrete mixer according to this invention is of the revolving barrel type, the improved construction and method of working being as follows:—

The barrel is corrugated longitudinally and is so operated that when working normally it revolves a desired number of times in one direction and then automatically reverses and revolves about the same number of times in the opposite direction; this alternate revolving action goes on for as long as is necessary thoroughly to mix the batch of material in the barrel, in which sloping shelves are so arranged as to cause the batch to travel to and fro along the barrel according to the direction of its rotation. When a batch is sufficiently mixed the barrel is revolved continuously in one direction until the discharge has



No. 177,814. Block-making Machine.



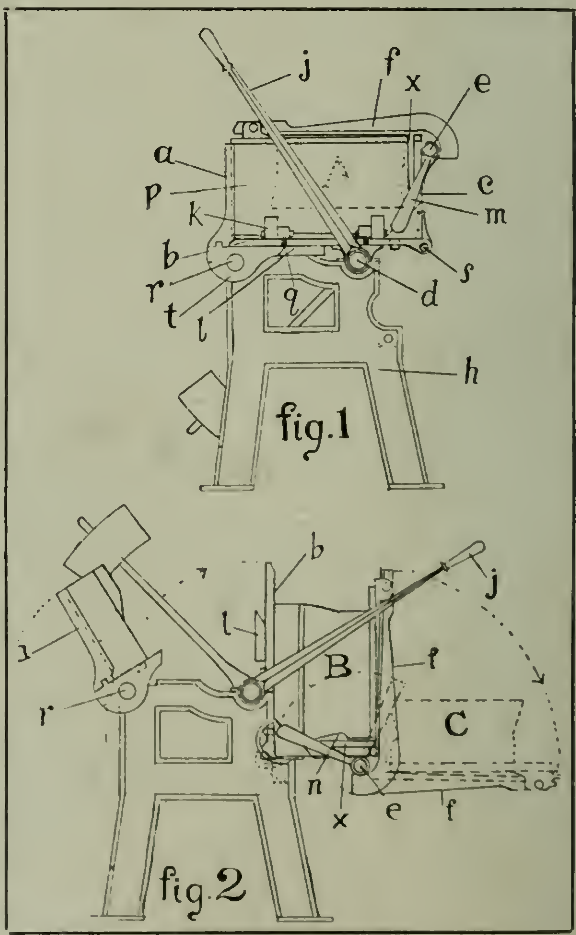
No. 177,977. Concrete Mixer

been effected by suitable parts inside the barrel. The barrel (A) is provided with a conical charging pipe (C) and discharging pipe (B), and is driven by rollers (M, N) upon a shaft (L) from a pinion (D) which engages one or other of the reversed bevel wheels (E, F), the clutches (G, H) of which are moved automatically by a connecting rod connected to a crank pin (K) operated by a ratchet wheel (J), the pawl (R) of which may be disengaged to allow continuous rotation of the drum in the same direction.

BLOCK-MAKING MACHINES.

[No. 177,991.—J. Thewlis, 2, Manor Terrace, Headingley, Leeds, York. April 1, 1921.]

According to this invention the moulding box is so constructed and arranged as to enable a double forward tilting movement to be given to the blocks or slabs when removing them from the machine. For this purpose one side, preferably the front (*c*), is hinged to the base (*b*) and secured at right-angles thereto by a locking device. The base and front thus arranged are adapted to be tilted through the first forward tilting movement by a hand lever (*j*), the opposite side being simultaneously tilted backward by cam or crank mechanism. At the front of the moulding-box and parallel to the upper edge thereof a shaft (*e*) is provided to carry two lever brackets (*f*) which hold the pallet and which are adapted to permit of the block or slab being tilted from the machine by the second forward tilting movement, the block or slab and pallet being then supported by the brackets ready for removal. In operation, the base (*b*) of the mould-box is moved from the horizontal to a vertical position (*Fig.* 2) around the pivot or trunnions (*d*) by means of the hand-lever (*j*), the side (*a*) being thrown back at the same time by the cam-block (*l*) working against the cam (*t*), which cam members serve to lock the mould when the parts are in



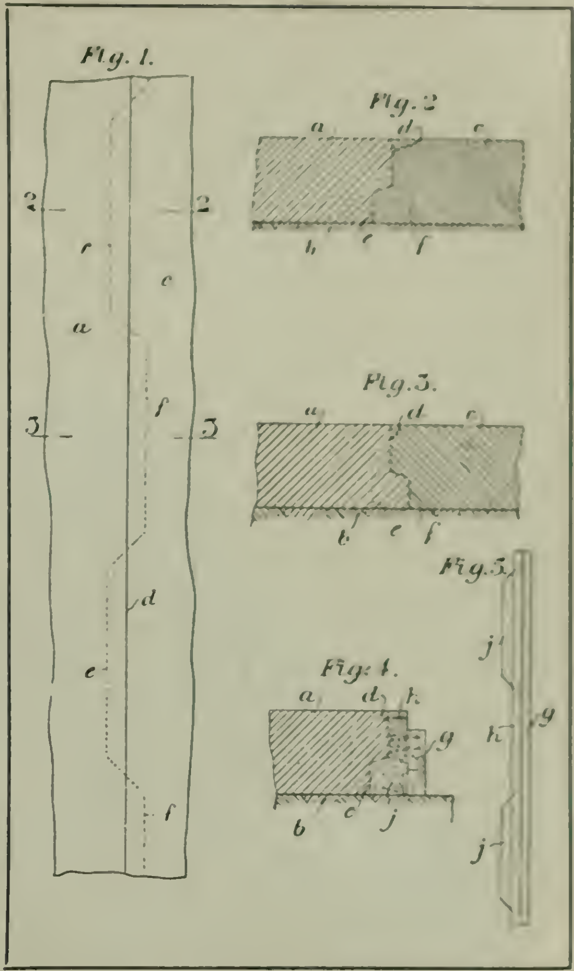
No. 177,991. Block-making Machine.

their normal positions. During this first forward tilting movement the part (*c*) is moved to the horizontal position, after which the second forward tilting movement is effected about the pivot (*e*) under the action of the hand lever (*m*), which partially rotates the shaft (*e*) situated parallel to and near the top edge of the front (*c*) of the mould box, to actuate the two lever brackets (*f*) which serve when in their lowered position (*Fig.* 2) to support or hold the pallet and its contents (*c*). Suitable stops are provided to limit the tilting of the parts, whilst any suitable locking devices may be attached thereto to lock the mould in its normal position during the moulding of the blocks.

LAYING CONCRETE.

[No. 181,930.—J. H. Walker, "Eridge," Shooter's Hill, Woolwich, London. May 18, 1921.]

This invention comprises a method of laying concrete in alternate bays and then filling in, the sides of adjacent slabs being interlocked in such a manner that when a rolling load (in the case of road surfaces) passes over a joint the weight of such load is at all times distributed over two or more slabs. The concrete (*a*) of one of the alternating bays is first laid on the prepared foundation (*b*), and the concrete (*c*) of the adjacent bay is laid after the concrete (*a*) has set sufficiently hard to permit of the mould or form confining the edge of the slab (*a*) being removed. The joint between the two slabs consists of a straight vertical joint (*d*) extending downwards from the surface of a roadway to about half the depth of the slab, whilst the lower half of the slab (*a*) has recesses (*e*) to the left of the vertical joint (*d*) and the projections (*f*) to the right thereof. The concrete (*c*), being moulded against the concrete (*a*) after the latter has set, has corresponding projections and recesses which result in the two slabs being interlocked together



No. 181,930. Laying Concrete.

in a vertical direction and also in a direction longitudinally of the joint (*d*) whilst leaving each slab free to contract away from the other in directions at right angles to the joint (*d*). A suitable form of mould for the edge of the slab (*a*) is shown in *Figs.* 4 and 5, and comprises two boards (*g* and *h*) spiked together and supported by short lengths of timber (*j*) which are of suitable lengths to give the required lengths of the recesses (*e*) in the concrete (*a*) and are spaced apart at suitable distances to give the required lengths of projections (*f*).

NEW BUILDING IN GREAT PORTLAND STREET.

The large new building illustrated on this page has recently been completed at 195–199, Great Portland Street, London, W.1, at the junction of Devonshire Street and Great Portland Street, for Messrs. Curry & Paxton, opticians.

This building is entirely constructed in mass concrete with reinforced concrete floors and pillars, no bricks being used at all in the construction except for flues. The original scheme for the entire building was designed in 1914. The continuation of the scheme, however, was delayed by the outbreak of the war and was not resumed until last year. Owing to the difficulty in obtaining

[Mr. E. Frazer Tomlins, Architect.

New Building in Great Portland Street, London, W.

bricks at that time, and on account of Government restrictions, it was decided to carry out the walls in mass concrete.

The general architectural plans were prepared by Mr. E. Frazer Tomlins, of 8, Church Lane, Hampstead, N.W.3, and the entire work was carried out under his supervision. The preparation of the reinforced concrete drawings was entrusted to Messrs. Edmond Coignet, Ltd., of 125, Gower Street, W.C.1.

The front of the building is composed of grey Aberdeen granite and Portland stone, backed with concrete. The interior of the building, more particularly the shops, is decorated in marble. The staircase is built of "Empire" patent stone. The ceilings and cornices throughout are constructed in run plaster work, and the floors are covered in oak parquet on the ground floor and deal block floors in the offices of the upper stories. All internal painted woodwork is omitted, and skirtings, window-board, etc., are of adamantine tiles in order to save expense in maintenance. The shop fronts are designed in mahogany with metal window-frames and steel sashes.

The building is composed of a basement, ground floor, mezzanine with a gallery, and five upper floors, with a flat mansard roof. The whole of the reinforced concrete work was designed in accordance with the rules of the London County Council. Round steel bars were used for the reinforcement throughout. The general contractors for the whole of the work were Messrs. Wm. F. Blay, Ltd., of Dowgate Hill, E.C.4. The tiled dados of the walls were supplied by Messrs. Simpson, of St. Martin's Lane. The foundation work and mass concrete was carried out by Messrs. Sabey & Co., of Kilburn. Among the other sub-contractors were the following :—Granite work, Messrs. V. Whitehead & Sons, Aberdeen ; marble work, Messrs. Farmer & Brindley, London, E.C. ; Portland stone work, The Ham Hill and Doulting Stone Co., Norton-sub-Handen ; wrought iron work, Messrs. F. & R. Edbrooke, Bristol, and Messrs. J. W. Singer & Sons, Frome ; metal casements and shop fronts, Messrs. R. E. Pearse & Co., Ltd., London, E.C. ; heating, Messrs. T. S. Knight & Son, London, W.1 ; electric wiring, Messrs. Strode & Co., London, N.W.1.

THE MANUFACTURE OF PORTLAND CEMENT.

AT the Northern Polytechnic Institute recently, Mr. H. R. Cox, M.C.I., Works Secretary to the Associated Portland Cement Manufacturers, gave an interesting address on "The Manufacture and Testing of Portland Cement."

The lecturer stated that up to 1885 the bulk of the world's cement was made on the banks of the Thames and Medway, the birthplace of the industry. Later it was discovered that many other districts contained materials from which good cement could be made. There were now two methods of manufacture in general use, known as the "wet" and the "dry." The wet was applied to naturally soft materials and the dry to such substances as limestone and shale. It was somewhat easier to make good cement by the wet than by the dry process. The "wet" process involved chalk digging by hand, or steam navvies and clay digging with grab dredgers. The chalk and clay were brought to the washmills in wagons each holding a definite weight (5 to 10 tons), 1 ton of cement requiring 1½ tons of chalk and ½ ton of clay. The washmills were in batteries of six, with screens between each having holes of an increasing degree of fineness down to [illegible] in. diameter. The proportions of chalk and clay were carefully regulated by the chemist, who took samples from the washmills every half-hour. The slurry leaving the washmills was so fine that barely 3 per cent. was retained on a sieve having 32,400 holes per square inch. The slurry was then pumped to storage and mixing tanks about 66 ft. diameter by 10 ft. deep.

In the dry process the materials were roughly crushed and then dried the driers being steel cylinders 50 ft. to 70 ft. long by 5 ft. to 6 ft. diameter, set at an incline and having a furnace at one end. The dry material was then elevated to hoppers and ground and mixed. From those mills the material went to silos, 40 ft. high by 14 ft. diameter, the silos being made so that the material might be mixed or changed as necessary. The next stage in either " dry " or " wet " process was burning or clinkering in a rotary kiln—a cylinder up to 250 ft. long and 10 ft. diameter, inclined to the horizontal ½ in. to the foot and revolving once per minute. It was lined with fire brick about 9 in. thick. At the lower end was a large hopper containing powdered coal so fine that only about 8 per cent. was retained on a sieve of 10,000 holes per square inch. This coal was blown into the kiln and burst into flame. The temperature reached 1,400° C. at the hottest part of the kiln, where the slurry was " clinkered." The whole process was under the complete control of the operator. The white-hot clinker fell into a cooler and was then ground in a ball mill. From the ball mill the cement passed to a tube mill, which carried on the grinding process by means of tough flint pebbles or steel pellets. That produced cement which gave a residue of only about ¼ per cent. on a 10,000 mesh sieve.

The cement, if ground without treatment, set very quickly and needed regulating. Until a few years ago 0·5 per cent. to 2·5 per cent. of gypsum was added, but the regulating now took place by a method of " hydration " invented by Mr. Bamber, which was carried out by blowing steam into the tube mill while grinding was going on.

Cement was invented about 100 years ago. It was now made in almost every country in the world, the ingredients being lime, silica, alumina, and a small quantity of magnesia, iron, and other elements. The details of the methods of manufacture varied, but all followed the general lines given above. About 2 tons of raw material and half a ton of coal were used for each ton of cement.

An elaborate system of testing was in operation at all stages, and chemists were continually taking samples at various stages in the manufacture. The salient feature of all tests was the degree of skill required upon the part of the tester if accurate results were to be obtained. That applied equally to such an apparently simple operation as sieving as it did to a chemical analysis.

The lecturer then detailed the tests required by the British Standard Specification, and indicated such points as the exact percentage of water that should be used in mixing, the operation of the Vicat needle and the details of cement briquettes for tensile tests. When cement had been obtained from a reputable manufacturer and was guaranteed to conform to the British Standard Specification the lecturer stated that any substantial variations in the tests should be very carefully scrutinised. In many cases they were the fault of the tests and not of the material itself. The colour of cement was no indication of its quality ; the weight again was unreliable. In obtaining cement for special purposes it was always advisable to describe the circumstances to the manufacturer, and to ask him to provide a cement to suit those requirements.

At the close of the lecture a demonstrator mixed cement for a setting test, soundness test, tensile test, neat and with sand, and showed how sieving should be carried out. The details of these operations, coupled with the accuracy required, were of great interest.

In the discussion which followed, Mr. G. A. Gardner, M.C.I., referred to percolation of water through cement concrete tending to become less with age, and the lecturer, in reply, stated that some amount of bridging of the aggregate took place, but cement properly mixed was quite impervious when set. In setting, cement was probably first in an amorphous condition and later on became crystalline, the change possibly having a closing effect upon the pores.

Mr. T. Scott, A.R.I.B.A., referred to the expansion of cement not air slaked and the need for air slaking. The lecturer stated that air slaking was no longer necessary owing to hydration during manufacture. Cement which was hot on delivery might simply have retained some heat from friction in grinding.

CEMENT NOTES.

By Our Special Contributor.

National Supremacy of Quality in Cement Manufacture.

British cement manufacturers have been accustomed to make two claims—the British invention of Portland cement and British supremacy of quality—but at the same time conceding that the chief developments of the manufacturing process have originated in other countries. The position as to national supremacy of quality appears to be challenged by Mr. R. K. Meade in a paper read before the Portland Cement Association of America, where he states that it is "to the credit of the American cement chemist that he can make cement superior to any in the world."

It is not to be disputed that from a theoretical standpoint it is possible to make good cements in most parts of the world, because minerals containing the necessary lime, silica, and alumina for cement manufacture are among the most widely distributed on the earth's surface. But the industry can only exist on a commercial basis, and in many districts the cost of producing a good cement from the available raw materials is prohibitive.

The quality of Portland cement depends largely upon the following factors:—

(1) Fine grinding and uniformity of composition of the raw material mixture.

(2) Thorough calcination.

(3) Fine grinding of the cement.

These constitute the chief operations in cement manufacture, and the more easily they are performed the greater is the prospect of commercial success and the greater is the probability of a high standard of quality in the finished article. When these operations become difficult through causes that will be mentioned later, cost of production and quality are in conflict, and the latter can only be maintained by increasing the cost or, if commercial considerations compel the cost of production to be limited, then quality must suffer.

It is a reasonable hypothesis that the best cement will be made in those countries where the manufacturing processes can be carried out with the greatest ease and the least cost. It remains to be considered, therefore, what are the conditions that make cement manufacture easy, and the most important of these is undoubtedly the nature of the raw materials. The ideal material would be one having the composition required for cement manufacture so that no mixing would be needed, but Nature has not provided such a material in sufficient quantities to be of practical importance. The nearest approaches are those chalk-marls, grey chalks, and argillaceous limestones with chemical compositions within 2 or 3 per cent. of the required cement raw-mix composition. But such materials have to be ground and mixed, and obviously soft chalk-marl and grey chalk take precedence over the limestones because they can be reduced to a fine state of division with comparative ease. A chalk marl can be washed to a slurry containing less than 5 per cent. residue on the 180 sieve for no more than 5 h.p. per ton, while a limestone may require from 20 to 40 h.p. per ton to be reduced to the same degree of fineness.

Chalk-marls are, however, not of frequent occurrence, and probably the next raw materials in order of ease of preparation for cement manufacture are white chalk and river mud or clays, such as those so largely used in the Thames and Medway districts. These materials can be finely ground with as much ease as chalk-marl, but the mixing of such chemically dissimilar materials as chalk and clay to the degree of uniformity needed is more difficult, and indeed never reaches the same degree of perfection that is obtained when Nature has performed the mixing to within 2 or 3 per cent. of the desired standard as happens in the case of chalk-marl. At the other end of the scale among the most difficult raw materials for the manufacture are hard pure limestones used in conjunction with hard shales, or argillaceous materials containing quartz. Such materials are difficult to grind finely and difficult to mix intimately.

Uniformity of composition of the raw material mixture is as important as fineness of grinding, and in this connection the wet process of mixing has immense advantages over the dry process. In the former, the ground raw materials in the form of liquid slurry can be conveniently stored in large quantities, and by means of stirring and circulation can be brought to a constant composition. With ordinary precautions, the proportion of carbonate of lime in cement slurry after mixing need never diverge more than 0·2 per cent. from any given standard.

The mixing of dry powders of varying composition that is necessary in the dry process is difficult and probably never attains the uniformity reached by the wet process. Even when two dissimilar materials such as limestone and shale, or cement stone and limestone, are crushed and fed together into a hopper in exact chemical proportions the material flowing from the hopper may vary in composition by 1 or 2 per cent. owing to the segregation which occurs in the hopper. This variation is not corrected during the processes of grinding, and the correct mixture can only be obtained by storing large bulks of the ground raw material in silos and mixing the contents of the latter by feeding together into conveyors. Experience shows that unless very extensive storage and an elaborate system of circulation are provided the dry process raw material mixture may vary by 1 per cent. in carbonate of lime from the desired standard. Such variation naturally affects the quality of the cement itself, because instead of being of uniform composition as in the wet process it is a mixture of high-limed and low-limed cements.

It is not intended to argue that good cements are not made by the dry process, but that, other things being equal, a better cement is made by the wet process.

The British manufacturers of cement, therefore, base their claims of superiority of quality on their general adoption of the wet process of manufacture and on their predominant use of soft raw materials. In the United States, the greater proportion of the cement is produced from hard raw materials on the dry process.

National standard specifications should be indications of the national standard of quality, and at the present time there is no practical difference between the standard specifications of Britain, the United States, Germany, and several other nations ; it is a matter for regret that the British Standard Specification is allowed to remain with conditions that are notoriously below the performances of the majority of the British brands of cement. If the British Standard Specification limits for strength were raised to the average standard of British quality there would be no dispute as to the national supremacy of quality.

PRECAUTIONS IN PAINTING CONCRETE.

When surfaces composed largely of Portland cement or concrete are painted it is often difficult to secure the necessary adhesion and, failing this, the paint is liable to flake and fall off.

Bituminous and asphaltic preparations are useful for protecting concrete from the weather and rendering them waterproof. Some of them may be applied cold ; others require to be heated before they will penetrate sufficiently to adhere well.

Varnishes of various kinds (usually with fancy names to disguise their origin) are also useful for the same purpose.

Oil cements, composed of powdered firebricks, galena flour and boiled linseed oil, are used for promenades, stairs, etc.

Mineral colours are used for interior walls. They must be adapted to the porosity of the surface to which they are applied and, for this purpose, are usually mixed with about 1½ times their weight of medium for application to cement-mortar or asbestos sheeting, but, for highly porous walls, a preliminary application of a mixture of one part of colour with three parts of medium should be given, and this should be followed by the usual coats of paint.

When a *glossy finish* is required, special materials—the nature of which is kept secret—are used, though occasionally the pores are closed by the application of magnesia fluate, and the surface is then polished mechanically.—*Beton u Eisen.*

THE INSTITUTION OF STRUCTURAL ENGINEERS.

CONCRETE IN RAILWAY WORK.

On November 16 last, the first meeting of the Institution of Structural Engineers (the new title adopted for the Concrete Institute) was held at No. 296, Vauxhall Bridge Road, S.W., under the Chairmanship of the President (Mr. E. Fiander Etchells).

After the minutes of the previous meeting had been passed, Mr. W. Marriott, M.Inst.C.E. (Engineer and Traffic Manager of the Midland and Gt. Northern Railways Joint Committee), read a paper entitled "Concrete on British Railways," in the course of which he dealt with many of the uses of concrete in railway work and from which we give the following abstracts:—

BRIDGES.

The only difficulty he had had with concrete, he said, had been that when buildings had to be pulled down for enlargement, so solid and sound were the structures that they were very difficult to remove, and the fact had also been noticed that the joists where they had been covered or embedded in concrete were as good as the day they were put in, and in many cases even had the mill bloom still on them. Since those days he had built scores of bridges of concrete, using, however, a brick facing, as being cheaper than shuttering, and even building in lime concrete, with excellent results; when one of those bridges near Cromer had to be taken down recently, the lias lime was as hard as a rock.

The use of pre-cast reinforced concrete in bridgework also offered many opportunities for economical construction. It was quite possible to make concrete girders for short spans complete and ready to lift into place. In other cases, where the steel girders were encased in concrete, the floor system was economically made of arch blocks. The arch blocks were pre-cast and could be put into place as fast as they could be handled. They were then covered up with concrete *in situ*, and trains could be, and had been, run over them within twenty-four hours. They formed a bridge floor which was economical in first cost, and also in maintenance, especially where trains were continually running underneath; no temporary woodwork or centering was required; and a good coat of limewhite every now and then was all that was necessary.

There were many ways of designing bridge floors. Some engineers preferred a flat slab, but he considered the arch was more scientific and economical. Some sixteen years ago he came to the conclusion that if concrete were to come to the fore weight must be reduced, and the articles must be scientifically designed. He was led to that conclusion largely by seeing an exhibition of concrete articles, which were so heavy and enormous as to be not only wasteful in material but costly to handle. All articles where possible should be hollow, or cored out to reduce all surplus material, and made much as cast iron was in moulds by casting. So many had gone on the lines of simply reproducing in concrete the wooden article they were replacing.

FENCE POSTS.

Fence posts to his design had been tested with such satisfactory results that many miles had been put up with great success. They were considerably lighter than the standard type of some large railways, and consequently a good saving was effected. The Great Northern Railway had adopted a similar post with every success.

The next step was to make a straining post. To get a straining post to stand the strain of eight wires tightly strained meant a huge post, more than men could lift about. It was not every one, perhaps, who realised the severe strain that could be brought to bear upon an end straining post. In trying many different types of reinforcement, it was found that the "Warren" type of bracing gave the best results for a minimum size post. That type of bracing was then adopted in various reinforcements, and tested beside other systems of reinforcement in the form of beams, etc., and in every case gave better results, even when only tied, and when welded the result was incomparably in favour of the "Warren" type.

SIGNAL POSTS.

The speaker adopted the "Warren" system for signal posts and erected the first post, 20 ft. high, in July, 1915. In March, 1916, there was a memorable blizzard, but the post, though unguyed, took no harm whatever, although scores of trees just behind it went down like ninepins, as did also telegraph posts for many miles. The system had been developed, and posts were now made up to 49 ft. long. Most of the principal railway companies had a large number, and two lines, at least, had adopted them as standard. There had been slight failures, but they were not due to any fault of the system generally but to faulty manufacture or transport and erection and general war difficulties, and the system had now progressed so far as large bracket signal posts. One of the chief difficulties had been, and was still, the education of the erectors, as one could not expect a concrete post to stand the throwing about a timber post would stand, or the deflection, but many posts had had to undergo rough usage. A great point in favour of concrete was that once the post was up and sound there would be no further expense on maintenance, and its life should be unlimited. One important factor was that unless the concrete were made waterproof the consequent corrosion of the steelwork arising from the permeating moisture might cause the concrete covering of the metal, where too thin, to burst off. He had spent much time in experiments and had found a simple remedy. Cement concrete could be made impermeable by exercising due care in selecting the concrete aggregate, especially the sand, but as suitable aggregate was not always obtainable in actual practice other means might be, therefore, at times necessary. The best method was doubtless to use a concrete which was waterproof in itself, and in which the reinforcement was protected by a sufficient thickness. In large structures it was possible to keep the reinforcement bars well inside (1½ in. to 2 in. from the surface), but in small structures a covering of not more than ¾ in. to 1 in. was, in many cases, possible. He always aimed at a minimum of 1 in. for posts or poles. In France and the Alps he found even in that dry climate the reinforcement, in many cases on the surface and even protruding, showing marks of rust which might ultimately bring the pole to grief.

For wrought work, like signal posts, which were usually painted, concrete could hold its own as to cost. It was not the same with telegraph poles, which were imported so cheaply, and which, by creosoting, had a life of from thirty to thirty-five years. In America deforestation and blizzards were turning attention to concrete poles. The question had been considered by the American Railroad Association, Telephone and Telegraph Superintendents' section, and it seemed that deforestation and cost of maintenance and replacement of wooden pole-lines compelled them to search for a permanent substitute. They arrived at the conclusions that the high maintenance costs of steel or metal poles (on account of frequent inspection and painting to prevent corrosion) placed a ban on their extended use; that well-made concrete poles would practically last for ever; that the cost of wood and concrete poles was comparable when the life of the pole line was considered; that the life of wooden pole lines depended greatly on the character of the soil and the insects contained in the soil; and that the large factors of safety allowed for wooden pole lines were not needed, due to the uniform behaviour of the materials.

There were miles upon miles of concrete poles in France, Switzerland and Italy, and he was quite convinced, from a durability point of view, that in the near future they would be adopted in this country for power lines. He had, however, never seen any finish abroad comparable with the finish of the poles in this country.

The question of transport of concrete articles was a very serious one, and it was most necessary that design should be carefully studied so as to make the article as light as possible consistent with its being strong enough. His system of reinforcement, by its box-like form with no diagonals, enabled almost all articles to be made hollow without reducing the strength. A short concrete girder used in various positions for signal rod fixings in solid wood would weigh 27 lb. per lin. ft., and in solid concrete 100 lb., but as designed and made, 40 lb. per lin. ft.; a signal post 27 ft. 6 in. over all in wood weighed 5½ cwts., if made of solid concrete 17 cwts., as made 15 cwts.; a 12 in. by 12 in. signal-post leg (for iron bracket) 26 ft. 6 in. long in solid wood would weigh 11 cwts., in solid concrete 56 cwts., as designed and made 20 cwts.

"Marriott" Reinforced Concrete Telegraph Post.

A pole which would be easily transportable had been designed by standardising ten different tapering lengths each of 4 ft.; each piece being separately reinforced, and within certain limits. Out of those lengths, kept in stock, sections of any desired strength could be selected and built into one pole by stringing them on main rods, at the place of erection, the main rods engaging the individual reinforcements in the sections. That pole had been specially designed to meet the needs of electrical power transmission lines in undeveloped and trackless countries, so that native labour might be used to carry the pieces inland.

Another pole for light lines was the cruciform section. A square pole 6 in. by 6 in. or 5 in. by 5 in. was about the smallest that could be made; the consequence was that the reinforcement was only about 3½ in. by 3½ in., and too near the neutral axis to give sufficient strength in many cases. The cruciform pole enabled the reinforcement to be spread and placed at such a distance from the neutral axis as to give a greater amount of strength for the same material, and had been specially designed for light telephone poles.

A very important point to be settled was the question of the factor of safety. For wood they were agreed on a factor of safety of 10, and for steel 6, and in each case that factor of safety referred to the ultimate strength of the material. Now there was a movement on foot to put reinforced concrete on a different footing, namely, that the ultimate strength of reinforced concrete should be based on the first crack. That was distinctly unfair, and, if adopted, would have a serious effect on its extended use since it would cause the cost to be prohibitive when compared with wood or steel for the same structures. He thought a factor of safety of 3 for ultimate strength would be sufficient for concrete power poles. It was, perhaps, necessary for the case of concrete roofs to be on a different basis.

Tests.—A round tubular pole made up of 4 ft. lengths, 24 ft. over all, was tested in a horizontal position, 5 ft. being firmly fixed and the load applied 18 in. from top leverage (17 ft. 6 in.). At 952 lb. the first faint crack appeared. At 1,960 lb. the pole failed. The calculated safe load was 344 lb. The factor of safety, safe load to breaking load, was 5·7. The factor of safety, safe load to first crack, 2·76. The safe load was calculated for 28 tons steel and 2,400 lb. per sq. in. concrete (breaking strengths).

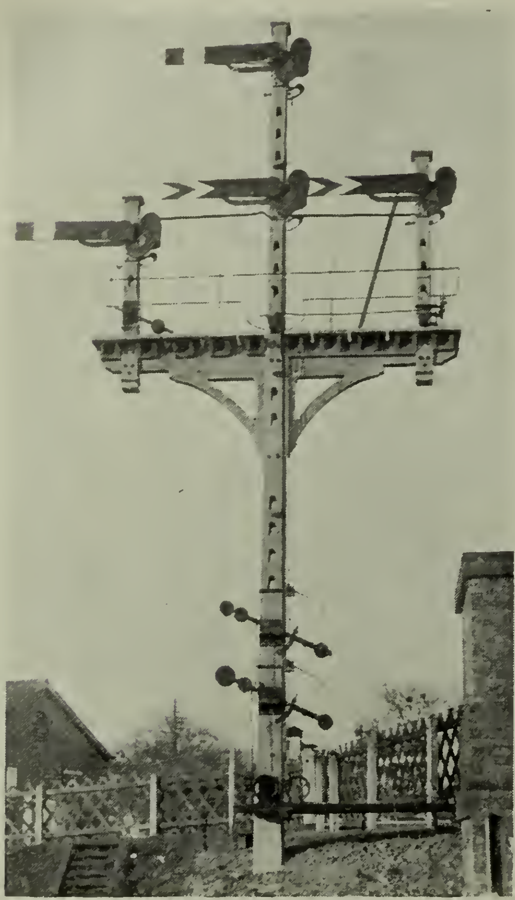
A test of a cruciform pole with a leverage of 15 ft. 8½ in. showed a factor of safety of 2·68 at first crack, while failure at 807 lb. showed a factor of safety of 6.

The question was an important one to manufacturers. Reinforced concrete, above all things, was a highly skilled product, and required skilled supervision and skilled workmen, as well as first-class material. The whole of the work, design, supervision, material and workmanship, must be of the highest grade. A great deal of harm had been done to the profession by unscrupulous people putting cheap and badly-designed products on the market, with serious results.

SLEEPERS.

The chief difficulty to be overcome in a satisfactory concrete sleeper was the lack of elasticity, and there were many points of importance to be taken into consideration in designing sleepers, a few of which were:—

(1) The continuous repetition of impact to withstand which resilience was necessary, as well as first-class concrete, excellent reinforcement, and the best workmanship.



LARGE REINFORCED CONCRETE BRACKET SIGNAL POST, "MARRIOTT" TYPE.

(2) Constant impact consolidated the sleeper bed, so that there was a tendency for the sleeper to become unevenly bedded, and it might even ride on its middle point. The top then got severe tension strains. If the track was trenched in the middle to avoid this, the trench must not be made too wide, otherwise the effect would be reversed with equally unsatisfactory results.

(3) The bearing area to ensure proper distribution of load required consideration.

(4) The weight of the sleeper required to be kept as low as possible which, therefore, limited the design and the strength.

(5) Maintenance men were somewhat prejudiced, and required to be trained in the management of a new kind of sleeper.

(6) Concrete sleepers were expensive, and would be so until a satisfactory type was produced, when they could be manufactured in bulk and the cost consequently reduced.

(7) Many of the best known sleepers were too lightly reinforced; others, notably the Italian, were over-reinforced, consequently cutting the concrete up into too small sections.

It could not yet be said that concrete sleepers were entirely satisfactory, but there were many entirely satisfactory replacements of timber in signal fittings, compensator frames, and general work, etc., where the carpenter could be completely eliminated; also in window frames, which was certainly one of the most economical items, being much cheaper than wood and most efficient, and equally suitable for wood or iron casements. Another satisfactory product was name boards.

IDEALS IN CONCRETING.

They had all, he trusted, ideals, and perhaps he might be forgiven if he gave briefly what his ideals were :—

(1) The very best cement. In that connection he would like to see a more rigid specification for reinforced concrete work. The British Standard Specification was, he considered, too wide. He had had some very bad cement which just passed the tests, and could not, therefore, be thrown out, and yet the men in the shops, by simply handling the cement, had been able to tell him it was likely to prove unsatisfactory, and time proved they were right.

(2) A good mixing machine and clean washed aggregate of regular size, the latter being perfectly dry before being used. That was most essential if a perfect mix was to be obtained, and he hoped in best work to see two mixing machines used. The first to dry mix—the dry mix to be then delivered to a machine for water to be added. The correct amount of water was very important, and it was necessary to have rather more than the textbook amount to get a waterproof concrete, and tamp well into the moulding box round the reinforcement. The steel should be clean with a high elastic limit. Mechanical tampers or vibrators, carefully used, ensured thorough tamping and the exclusion of all air bubbles, making a dense, homogeneous, and consequently permanent product irrespective of waterproofing compound.

(3) The scientific and practical training of the supervisory staff, as well as highly-trained workmen.

Dr. L. R. Wentholt, Engineer-in-Charge

of the Meuse Lock on the Meuse-Waal Canal, in those works had added pulverised trass to the cement, the theory being that Portland cement contained too much lime (CaO). It was possible to make a chemical compound of the surplus of lime and silica (SiO_2) by adding trass, which compound of lime and silica did not dissolve in water. The trass cement was composed of one part cement and one-half part trass. By adding trass to Portland cement the proportion between the main constituents, lime, alumina and silica, might be altered as desired. The advantage in Holland in using that instead of cement alone was that in that country the price of trass was only half the price of cement.

After referring to Roman cement, he said there was a new cement which was not yet much known in England, and very little in France, called *ciment fondu*. Through the kindness of Messieurs Quinquet and Ruffieux, the Chief Engineer and Assistant Engineer respectively of the P.L.M., he had had a report of which the following was a brief résumé. Originally the subject of a patent, it was a mixture of limestone and bauxite (aluminium ore composed essentially of aluminium hydroxide with iron hydroxides, clays, etc.), fused with coke in a water-jacket. At present it was manufactured in an electric furnace. The fused mass was cooled and broken into small pieces which were ground to powder in a ball mill. It agreed approximately with the following analysis :—

S_1O_2	about 10 per cent.
Al_2O_3	,, 40 ,, ,,
Fe_2O_3	,, 10 ,, ,,
CaO	,, 40 ,, ,,

The various mixtures fused at about 1400 deg. ; the fused cement was very fine, and usually left only 4·50 per cent. of its weight on a sieve of 180 meshes to the inch. It had a high initial strength, and setting began at 1½ hours and finished at 3½ hours. The temperature in a gauging might rise as high as 150 deg. during the process of setting. As it soon attained considerable strength it was used during the war for mounting heavy guns. It resisted water containing sulphur. That cement should be valuable in special work where sulphur was present and, no doubt, was the precursor of other discoveries which would aid reinforced concrete in the future, as no doubt many improvements would be made as soon as the nation laid aside its prejudices.

DISCUSSION

Mr. W. J. H. Leverton, who proposed a vote of thanks to the lecturer, said it was surprising that concrete engineers did not make more use of the arch, because the main strength of concrete was in compression ; where there was tension steel was put in, but with an arch the compressive strain was used and steel was not wanted.

Mr. D. B. Butler, who seconded the vote, said in the use of concrete in railway work this country was far behind American practice, from which there was a great deal to learn. The reason for the economy of concrete was that once the building was completed and the material properly made it was practically everlasting, provided the reinforcement was sufficiently protected to prevent rusting. He agreed that there should be a more rigid specification for Portland cement. His experience was that the English, and most of the foreign, cements developed a

Line of Reinforced Concrete Telegraph Poles carrying Twenty-two Wires.

strength at least 50 per cent. above the minimum required by the British Standard Specification, and many developed a strength of 100 per cent. above. The British Standard Specification should also be strengthened with regard to fineness of grinding. He doubted whether men in the shops could tell whether a cement was good or bad simply by handling it. The lecturer was in favour of cement produced by the old-fashioned intermittent kiln as against that produced by the rotary process; but he (the speaker) believed at least 95 per cent. of English cement was produced by the rotary process at the present time, which was a strong argument in favour of the quality of that product. Also, it was more economical. Discussing the addition of trass to Portland cement, Mr. Butler said trass was a volcanic product, chiefly silica and alumina. The silica was mainly soluble, and the theory was that the soluble silica in the trass combined with the lime in the cement which was set free when the cement set, and so formed a stronger product. Also, it prevented the cement being attacked by sea water. Some years ago he had made a report on the use of trass, and the cement with trass added to it certainly gave better results than the pure cement, especially in sea water. *Ciment fondu* was made in the south of France on a totally different principle from that on which Portland cement was made. After giving some particulars of that type of cement, he said that although it was expensive it might be used successfully in many cases where quick strength was required.

Mr. Steinberg, referring to the data on which poles for carrying electric transmission lines were designed, said the factors to be considered included such problems as windage, and the possibility of one or more of the cables breaking and the pole being in consequence subjected to an unbalanced pull. He believed before long the Ministry of Transport would formulate instructions for the guidance of those designing such poles. With regard to *ciment fondu*, if that could be produced on a commercial basis it would have a revolutionary effect on reinforced concrete construction. He referred to piles having been made in *ciment fondu* and driven in three days; it had also been used for lengthening piles, and the lengthened piles had been driven in two days.

Mr. F. J. Rouse referred to his personal experience of the use of pozzuolana in Greece.

Mr. Marriott, replying to the discussion, said he agreed with the remarks as to the use of the arch; he always used it when he could. In the design of reinforced concrete poles he took the wind strain at the sides alone; he did not consider the end load brought about if a cable broke, because it was bound to slip through the insulator quickly and the load would alter. If they were right for windage they were all right. Unfortunately, there was no fixed rule to-day. Some people demanded a pole with a factor of safety of 6, and some asked for a factor of safety of 3, and they simply designed a pole for the weights, for the spans, and for the factor of safety asked for. He hoped the Institution would do something to get the British Standard Specification amended. There were plenty of brands of cement that could be depended upon for reinforced concrete work.

THE HONORARY SECRETARYSHIP.

During the meeting it was announced by the President that Mr. Yeatman had accepted the position of Honorary Secretary of the Institution under the new rules.

BOOK REVIEW.

The Design of Mill Buildings and the Calculation of Stresses in Framed Structures. By Milo S. Ketchum, M.Am.Soc.C.E.

Fourth Edition [illegible] London: The McGraw-Hill Book Co. [illegible]

This new edition of Ketchum's "Mill Buildings" is much enlarged from the first edition, and has been entirely rewritten. The scope of the book has been enlarged by the addition of a concise discussion of the calculation of the stresses in statically indeterminate trusses and frames, several problems in framed structures, and detailed designs of a crane girder, a roof truss and a steel frame mill building.

The book is intended to serve as a textbook for students of structural engineering as well as a reference book for engineers on the subject with which it deals. As a textbook its explanations of fundamental theorems in applied mechanics are none too clear. The wording and the notation is rather muddling. Authors cannot give too much attention to simplicity and clarity of style and should adopt a self-evident algebraic notation like that of the Concrete Institute. The student must naturally do some work himself, but his way should be made as easy as possible. Professor Ketchum might well study the style of Professor Jacoby's "Structural Details" or Professor Merriman's "Elements of Mechanics." As might be expected the book demonstrates only the elastic theory in regard to calculations of structural members. American engineers seem well trained as a rule, but the training is like that in our colleges, in the hands of mathematicians who themselves have been brought up on the theory of elasticity. The American professors certainly more frequently than ours have practical experience and often practice as consultants. There seem fewer engineers trained by early pioneers who had far more practical knowledge than theory, and for that reason American practice in design of large structures is often far too standardised, and extravagant. We fortunately in this country rely upon the experience and practical common sense of our engineers. We are by no means underrating theory, but we do ask for it to be related to facts derived from experiment and experience. The study of what happens beyond the elastic limit as regards steel, and the study of materials that are brittle or develop plastic deformation at low stresses has been largely ignored by textbook writers. In practice plastic deformation alters the distribution of stress and brings many of the conclusions drawn in this book as regards bending moments and stresses in beams into conflict with facts. Professor Heyn has called attention to the need for taking plastic deformation into account in advanced theoretical calculations of the strength of materials. In a book review there is not a proper opportunity to discuss such a matter in detail. We but draw the author's and readers' attention to the omission. We have yet to see a really scientific and practical treatise on the design of structures. This does not mean that we do not consider Professor Ketchum's book a good one. It contains much valuable matter, and it should be possessed by every student and practitioner of structural engineering. But it should be used with discretion.

The book contains a good deal of information about details of roof coverings, gutters, downpipes, roof glazing, skylights, ventilators, windows, and so on, but there is very little demonstration of principles in such respect and the information fails to just hit the mark so as to be of real practical use to the designer. This is a defect that is too usual in books of this kind. They seem to be made up of data picked out of trade catalogues, which are often designed to leave something undefined to attract an enquiry from a possible user. The author of a handbook ought however to give only thoroughly detailed information, such as is to be found in books on building construction, though even they are often lacking as regards up-to-date practice.

H. K. D.

CORRESPONDENCE.

REINFORCED CONCRETE REGULATIONS.

SIR,—How much longer are we to read in municipal journals that reinforced concrete structures are turned down and massed concrete structures favoured, due to the governing bodies not granting the same term loan for reinforced concrete as for massed concrete.

Instead of short term loans for reinforced concrete work, surely the reverse should be the case? Why should municipalities be encouraged to waste the taxpayers' money by building in mass concrete, instead of by the cheaper and more efficient method?

Is it not time engineers throughout the country combined to force the governing powers in this matter to alter their fifty years behind the times ideas and methods —or turn them out of office in the same way as the Government of a country has eventually to submit to the will of the people?

Safety in construction is *essential*, but the safety that some of our out-of-date governing bodies would force us to submit to is highly dangerous, and retards national progress. Anything which you can do through the medium of your journal to give this important matter prominence will be doing a national service, and earn the gratitude not only of engineers and of those interested but of the already highly-burdened taxpayer.

It is no good waiting for others to move in this matter. I would therefore appeal to engineers and others interested throughout the country to write their views on the matter, and those in favour to agree to support a combined movement to get these unjust, unreasonable and wasteful methods adjusted.

ARTHUR W. C. SHELF.

Engineers' Club.

[*** This subject is referred to in our Editorial pages.—ED.]

MILD VERSUS HIGH-TENSILE STEEL.

SIR,—My attention has been drawn to Mr. Shelf's letter in your November issue.

I imagine Mr. Shelf is correct when he says that neither I nor Mr. Workman understands properly the contention he puts forward. We may differ as to the reason for this.

But let us examine Mr. Shelf's contention.

He says a $\frac{7}{8}$ in. square H.T. bar stressed to 76,000 lb./in.^{2} gives 58,185 lb. ultimate, and a $1\frac{1}{8}$ in. diameter round M.S. bar stressed to 60,000 lb./in.^{2} gives 59,640 lb. ultimate.

Immediately underneath he gives a diagram in which these figures are given as 58,185 and 58,340 (instead of 59,640), and a note that: "The above figures—58,185 lb. and 58,340 lb.—are the *tensile stresses* of each section" (yet he has just told us that the tensile stresses were 76,000 lb./in.^{2} and 60,000 lb./in.^{2} respectively).

He goes on, "The safe working stress would be one-fourth of these figures," that is, about 14,500 lb./sq. in. in both cases—while the whole point of his argument was that it was safe and desirable to stress the H.T. steel to a higher stress.

Is it any wonder that neither Mr. Workman nor I can understand his contention? It is clear that Mr. Shelf does not fully understand what stress is, since he confuses stress and total tension; on this kind of reasoning it would be easy to prove anything, but very dangerous to be influenced by the argument.

As for the last paragraph, I disclaim grasping even the shadow of his contention. If we are going to talk theory, let us talk theory.

I object to decrying correct theory and mathematics and then bringing out an argument which is entirely theoretical and only differs from the other in that it contains mistakes.

OSCAR FABER.

[*** There seems no useful purpose in continuing this discussion.—ED.]

DATA FOR PRICING REINFORCED CONCRETE.[1]

MATERIALS DELIVERED 4 MILES FROM CHARING CROSS

		s.	d.
Best Washed Sand	per yard	16	6
Clean Shingle, ¾ in. mesh	,,	14	6
,, ,, ½ in. mesh	,,	13	6
Best British Portland Cement	per ton	63 to 68	0
"Ferrocrete" Portland Cement	10s. per ton extra		

Boarding for Shuttering—		Sawn		Wrot	
1 in.	per square	23	6	27	9
1¼ in.	,,	26	6	33	0
1½ in.	,,	35	6	41	0

Sawn Timber for Struts and Supports—

3 in. by 4 in.	from £20 per standard.
3 in. by 6 in. and 3 in. by 7 in.	,, £22 ,,

Mild Steel Rods for Reinforcement—

		s.	d.
⅝ in. to 2⅞ in. Rounds	per cwt	13	6
$\frac{9}{16}$ in. to ½ in. Rounds	,,	13	6
⅜ in. Rounds	,,	14	6
¼ in. Rounds	,,	16	6

MATERIAL AND LABOUR INCLUDING 10 PER CENT. PROFIT

(Based on Contracts up to £2,000.)

Portland Cement Concrete well mixed with Clean Water in proportion 1 : 2 : 4—

		s.	d.
Do. do. in foundation	per yard cube	45	0
Do. do. in columns	,, ,,	50	0
Do. do. in beams	,, ,,	50	0
Do. do. in floor slabs 4 in. thick	per yard super	5	3
Do. do. in floor slabs 6 in. thick	,, ,,	7	9
Do. do. in floor slabs 9 in. thick	,, ,,	11	3
Do. do. in walls 6 in. thick	,, ,,	8	0

(Add for hoisting 3s. 6d. per yard cube above ground-floor level.)

Steel Reinforcement, including Cutting, Bending and putting into Position and securing with Stout Binding Wire—

		s.	d.
From ¼ in. to ⅜ in.	per cwt	26	0
,, $\frac{9}{16}$ in. to ½ in.	,,	24	0
,, ⅝ in. to 2⅞ in.	,,	23	0

Shuttering—

		s.	d.
Shuttering and Supports for Concrete Walls (both sides measured)	per square	60	0
Centering to Soffits of Reinforced Concrete Floors and Strutting, average 10 ft. high	per square	50	0
Do. do. in small quantities	per ft. super	0	10
Shuttering and Supports to Stanchions for easy removal, average 18 in. by 18 in.	per ft. super	0	11
Do. do. as last in narrow widths	,, ,,	1	1
Do. do. to sides and soffits of beams average 9 in. by 12 in.	,, ,,	1	1
Do. do. as last in narrow widths	,, ,,	1	3
Raking, cutting, and waste to shuttering	per ft. run	0	3
Labour, splay on ditto	,, ,,	0	2
Small angle fillets fixed to internal angles of shuttering to form chamfer	per ft. run	0	3

[1 This Data is specially compiled for *Concrete and Constructional Engineering*, and is strictly copyright.]

MEMORANDA.

Reinforced Concrete Decks in Insulated Holds.

We take the following from the *Marine Engineer* :—" When a hold and the 'tween decks above it have to be separately insulated the dividing deck requires to be insulated on both sides. This practice in the past has been unavoidably expensive, heavy and complicated. With the introduction of the Pohlmann 'Thermos' system of insulation, in which a light non-conducting concrete, combined with air cases in which the air circulation is restricted, is used for covering the steel surfaces of the ship's holds, the idea naturally occurred to eliminate the steel dividing decks and substitute reinforced concrete decks instead. Several applications of the idea are being used in vessels being built by the Bremer Vulkan and Deutsche Werft companies. The construction and erection of the deck is carefully detailed, and the complete approval of the Germanischer Lloyd has been obtained for the design. The experience of the Bremer Vulkan and the Deutsche Werft both show that, with a convenient spacing of pillars, the concrete deck is slightly lighter than the steel, while the cost is almost exactly half. The system of construction is rapidly gaining favour, and is to be adopted in further vessels under construction at these yards and also in vessels being built by Messrs. Blohm & Voss and the Deutsche Werke, Kiel. The system has much to commend it from the point of view of first cost, upkeep and cleanliness."

New Floating Dock at Southampton.

Four tables of reinforced concrete, each with 94 legs, are, it is stated, to be constructed in Southampton Harbour for the mooring of the world's largest floating dock now being built on Tyneside for the London and South-Western Railway Company at cost of about £1,000,000. The contract for the construction of these "dolphins" has been placed with Messrs. A. Jackaman and Sons, Ltd., of Slough. Three hundred and seventy-six piles of reinforced concrete, each 60 ft. long and weighing 8 tons, will be driven 18 ft. into the bed of the harbour from wooden floats anchored over the site. Round the heads of these piles will be constructed the four rectangular slabs forming the dolphin tops, each 70 ft. long, 32 ft. wide, and 5 ft. thick, weighing about 1,000 tons. The dock will be moored to the dolphin by steel lattice booms, 70 ft. long, and fitted with "universal" joints at each end to allow of the free movement of the dock.

Concrete Roads at Sheffield.

The report of the Sheffield Highway and Sewerage Committee for the year ended March 31, 1922, states that during that period the money granted for relief works was spent chiefly in converting bouldered streets to concrete roads. The length dealt with was 3,411 yds., comprising 31 streets. The area of concrete was 21,300 yds.

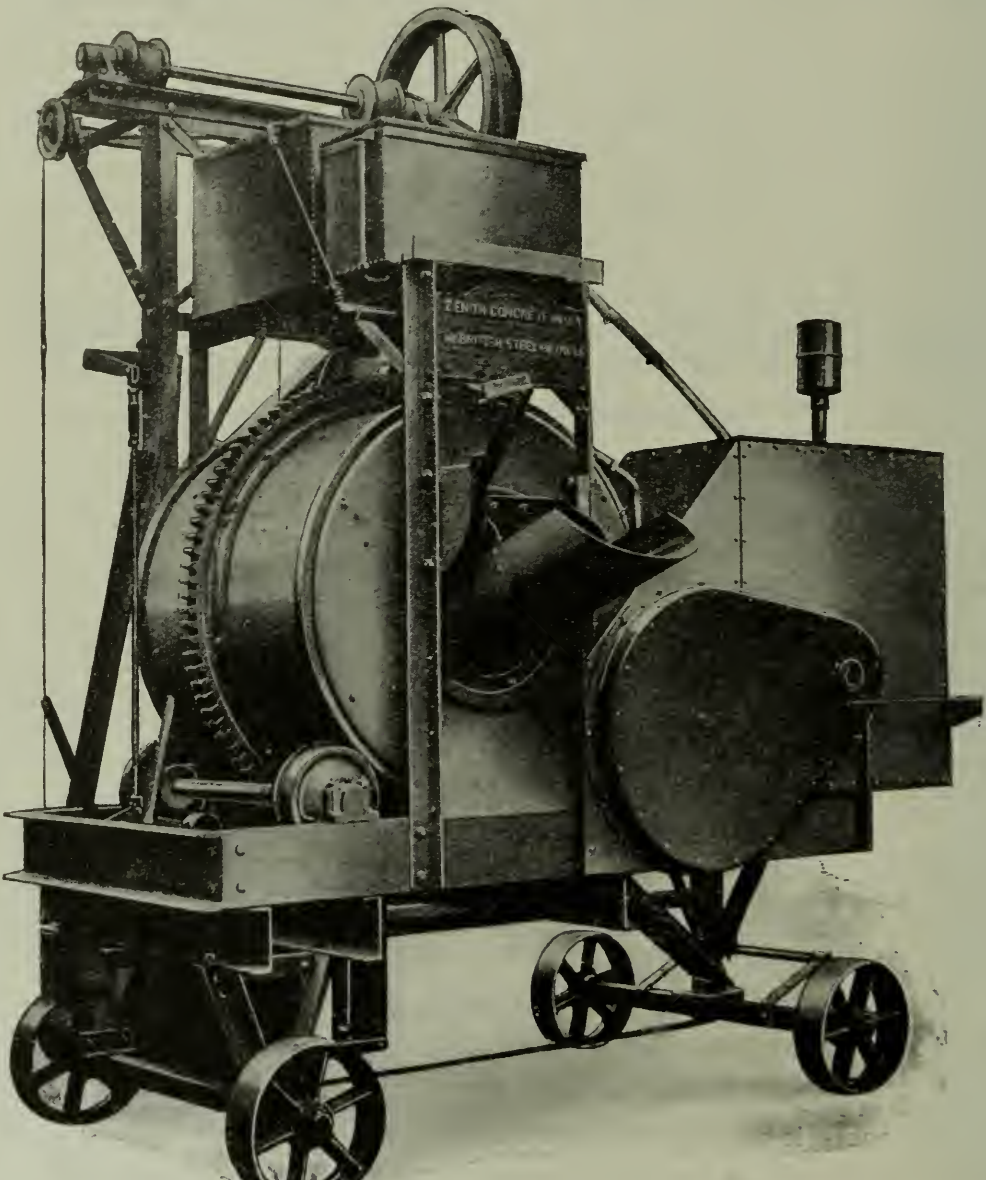
Pneumatic Tyres for Concrete Carts.

In order to avoid the separation of the coarse aggregate from the remainder of the mix whilst concrete is being taken over rough tracks in handcarts, an American contracting firm has fitted its handcarts with pneumatic tyres, which, in addition to lessening the vibration, makes the carts more easy to handle.

Cost of Steel, Concrete and Brick Stacks.

Relative costs of smokestacks for power plants up to 600 h.p. are given in the report of the committee on the modernisation of stationary power plants of the American Railway Association (Mechanical Division). Steel stacks, it is stated, increase in cost directly in proportion to the boiler horsepower of the plant, due to duplication of stacks for the larger plants. The cost is much lower for small plants, but gradually approaches that of concrete and brick as the size of the plant increases. Concrete stacks decrease in cost per boiler horsepower as the size of the plant increases, the cost being slightly higher than that of brick for the same size of plant above 500 h.p., and less for plants below 500 h.p. There is no appreciable upkeep to a concrete stack. Brick stacks require pointing up from time to time, while steel stacks require painting annually or bi-annually.

"ZENITH" CONCRETE MIXER



Zenith Mixer of Output Batch Capacity ½ cu. yd. Complete with Petrol Engine and Side Loader. As delivered ex-stock.

Write for particulars of

ZENITH STEEL MAST CONCRETE CHUTING PLANT.
ZENITH STEEL TOWER.

Works: CLAYDON, IPSWICH.

Concrete Machinery Department:

BRITISH STEEL PILING CO.,
Dock House, BILLITER STREET, E.C.3.

PROSPECTIVE NEW CONCRETE WORK.

BEXHILL.—*Parade.*—A scheme is in hand to continue the parade from its present termination at West Marina to the eastern end of the parade at Bexhill, a distance of two and a half miles. The estimated cost is £300,000, and will take about three years to complete.

BIRMINGHAM.—*Bridges.*—Subject to the Ministry of Transport contributing 50 per cent. of the estimated cost of £60,000, the Corporation proposes to reconstruct the railway bridges at Bromford Lane and Brighton Road.

BLACKPOOL.—*Swimming Bath.*—The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £50,000 for the construction of a swimming bath.

BOURNEMOUTH.—*Pavilion.*—The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £100,000 for the erection of a Pavilion.

BRIGHTON.—*School.*—The Brighton Education Committee has decided to make an application to the Ministry of Health for sanction to borrow £14,300 for the erection of a new school in Loder Road.

BURTON-ON-TRENT.—*Gasworks.*—The Ministry of Health has held an inquiry into an application by the T.C. for sanction to borrow £36,100 for extensions in connection with the gas undertaking.

CHELMSFORD.—*New Road.*—The Ministry of Transport has agreed to make a grant of 50 per cent. of the estimated cost of £35,000 for constructing a new road from Springfield to Chelmsford Railway Station, and the work is to be commenced at once.

CLEATOR MOOR.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £10,000 for sewerage and sewage disposal works for the southern portion of the district.

COLWYN BAY.—*Gasworks.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow £40,860 for extensions in connection with the gasworks.

DORKING.—*Sewage Works.*—The U.D.C. has decided to carry out improvements at the outfall works at an estimated cost of £2,000.

DUDLEY.—*New Roads* —The Borough Surveyor has received instructions from the Corporation Public Works Committee to proceed with the construction of a new road from Netherton New Road to Baptist End Lane, at an estimated cost of £6,500, and a new road from Wolverton Road to Watson's Green, Dudley, at an estimated cost of £7,270.

DYSERTH.—*Sewage Works.*—The St. Asaph R.D.C. is considering a scheme of sewage disposal for the townships of Dyserth and Toyn at an estimated cost of £15,000.

FRECKLETON.—*New Road.*—The Lancashire C.C. has approved the arrangements for constructing a new road, 2¼ miles long, to the centre of Freckleton village, at an estimated cost of £60,000.

HAM.—*Sewage.*—The U.D.C. has applied to the Ministry of Health for sanction to borrow £10,000 for sewerage and sewage disposal works.

HARROW.—*Swimming Bath.*—The Ministry of Health has given its approval to a loan of £9,500 for the construction of an open-air swimming bath.

HASTINGS.—*Groynes.*—The Corporation has decided to apply to the Ministry of Health for sanction to borrow £744 for lengthening the concrete groynes at Breeds Place and East Parade by 70 to 80 ft.

HOLMFIRTH.—*Sewage Works.*—The Ministry of Health has given provisional sanction to the U.D.C. to borrow £20,000 for sewage disposal works.

HUDDERSFIELD.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £133,300 for the extension of the sewage disposal works.

LONDON (Highbury).—*Open-air Bath.*—The L.C.C. is recommended to approve estimates, amounting to £26,030 for the construction of open-air swimming baths at Highbury Fields, and Southwark Park.

LONDON (Peckham).—*Swimming Pool.*—The L.C.C. has decided to construct an open-air swimming pool, having a water area of approximately 5,000 sq. yds., at Peckham Rye. The pool will be built of concrete.

LOUGHBOROUGH.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the T.C. for sanction to borrow £21,215 for the extension of the sewage disposal works.

LOWESTOFT.—*Defence Works.*—The Ministry of Health has held an inquiry into an application by the Corporation for sanction to borrow £100,300 for the construction of a sea wall, breakwater, and groynes.

PAIGNTON.—*Promenade.*—The U.D.C. has instructed the Surveyor to put in hand the work of extending the Preston Promenade, and to arrange for the necessary repairs to the sea-wall.

PAIGNTON.—*Tennis Courts.*—The Surveyor to the U.D.C. has been instructed to submit an estimate of the cost of converting some of the grass tennis courts at Queen's Park into hard courts.

PRESTATYN.—*Road.*—The U.D.C. is considering the construction of the Gronant Road. It is stated it is proposed to use reinforced concrete.

SKEGNESS.—*Sewage Works.*—The Ministry of Health has held an inquiry into an application by the U.D.C. for sanction to borrow

£16,500 for the extension and improvement of the sewage disposal works.

SOUTH SHIELDS.—*Swimming Bath.*—The T.C. has prepared a scheme for improving the beach. It is proposed to construct an open-air sea-water swimming bath, 176 ft. long by 50 ft. wide, together with shelters, tennis courts, and a children's playground; also to extend the concrete platform at the seaplane station in order to form a promenade to the South Pier. The total cost of the scheme is estimated at £30,000.

TYNEMOUTH.—*Sea Defences.*—The T.C. has adopted a scheme for the preservation of the sea banks at Tynemouth. The scheme includes the construction of a low-level promenade and a bathing pool. The total estimated cost is £60,000 to £70,000.

URANA.—*Bridges.*—The Urana Council, New South Wales, will borrow £10,000 for replacing with reinforced concrete eight timber bridges.

UXBRIDGE.—*Reservoir.*—The Surveyor to the U.D.C. has been instructed to prepare plans and specifications for a reinforced concrete reservoir with a holding capacity of one million gallons.

VENTNOR.—*Tennis Courts.*—The U.D.C. has decided to apply to the Ministry of Health for sanction to borrow £1,000 for the purchase of land for hard tennis courts.

WEST MERSEA.—*Sewage.*—The Ministry of Health has held an inquiry into an application for a loan of £10,000 for sewerage and sewage disposal works.

TENDERS ACCEPTED.

CHISWICK.—*Sewers.*—The Chiswick U.D.C. has accepted the tender of the Consolidated Construction Co., Ltd., at £7,436, for the construction of about 4,000 ft. of 36-in. concrete tube surface, water sewers, and 2,700 ft. of 18-in. stoneware surface-water outfall sewer.

CLEETHORPES. — *Concrete Slabs.* — The U.D.C. has accepted the tender of the Croft Granite, Brick and Concrete Co., Ltd., of Croft, near Leicester, for the supply of 2,500 concrete slabs.

GLASGOW.—*Bridges.*—The Statute Labour Committee recommends the Corporation to accept the tender of Messrs. Melville, Dundas & Whitson for the construction of a ferro-concrete bridge over the Cart at Riverford Road, and also the tender by the same firm for a reinforced concrete bridge over the Monkland Canal at Cumbernauld Road. The estimated cost of the latter bridge is £48,553.

HULL.—*Basement.*—The T.C. has accepted the tender of Messrs. C. Greenwood & Sons, Hull, at £877, for the construction of a ferro-concrete basement for the East Hull baths.

NEWARK.—*Sewage Disposal Works.*—The Corporation has accepted the tender of Messrs. W. Moss & Sons, Ltd., Loughborough, at £14,158, for the construction of concrete detritus chambers, screening chambers, storage tank, etc.

SELBY.—*Bridge.*—The U.D.C. has provisionally accepted the tender of the Yorkshire Hennebique Co., Leeds, for the construction of a ferro-concrete bridge over the Selby dam.

WOLVERHAMPTON. — *Foundations.* — The T.C. has accepted the tender of Mr. M. A. Boswell, at £348, for concrete boiler foundations at Cosford Pumping Station.

RECENT PATENT APPLICATIONS.

178,060.—J. Graber: Presses for cement pipes or tubes.

185,918.—H. Wade (W. C. Griesser): Subaqueous structures.

186,110.—Mouchel & Partners, Ltd., and J. S. E. De Vesian: Reinforcement of roads, platforms and foundations.

186,115.—C. F. Whiffen: Reinforcements for concrete slabs, beams, posts, piles, sleepers, and slab walls.

186,165.—P. J. White: Concrete building blocks.

186,355.—L. W. De Hamon: Compositions for the manufacture of building blocks, slabs, and tiles.

186,431.—S. Wright: Apparatus for use in making concrete slabs.

186,531.—Sir E. Airey: Apparatus employed in the construction of concrete walls, pillars, and piers.

186,637.—G. English: Construction of floating-docks, dry-docks, caissons, reservoirs, and structural steelwork.

186,660.—R. Last: Machines for ramming oval concrete pipes.

186,671.—L. Williams: Rock-breaking machines.

186,731.—E. N. Stredwick: Method of constructing buildings in concrete.

186,734.—T. J. Gueritte and L. G. Mouchel & Partners, Ltd.: Piles.

186,739.—Ryan Manufacturing and Construction Co., Ltd. and J. Ryan: Moulding apparatus for manufacturing concrete blocks or slabs.

186,745.—A. W. Rammage and G. H. Pittaway: Concrete slabs or block walls.

186,809.—E. Darby: Buildings.

187,103.—H. E. Williams: Concrete block moulding machines.

187,173.—A. G. Fentekew and J. B. Rowe: Centering for concrete floors and other structures.

TRADE NOTICES.

Messrs. Charles Brand & Son are using four combination "Insley" mast hoist concrete chuting plant and material elevator equipments in connection with the erection of the railway extension work at Golders Green, Hendon. In the design of the equipment the mast is a sectional steel mast, all parts being interchangeable and adapted to working from 20 ft. to 150 ft. in height. The material elevator platform is being used for hoisting up brick and mortar for the brick arches, after which the plant is converted into a concrete hoisting and chuting plant. The time to change from the use of one plant to the other is about 15 minutes, i.e., the time necessary to disconnect the material elevator from the guides of the mast and hook the hoist line on to the automatic dump concrete hoist bucket. The chuting distribution of the concrete from the steel mast is handled by swivel head chute sections, parabolic in form, and made from copper steel sheets. The chutes are carried on one-wheel trolleys run on a suspension cable, which is carried from the steel mast over the point desired. The plant is supplied by Messrs. Christmas, Hulbert & Walters, Ltd., of Caxton House, Westminster, who are the European agents for the Insley Company.

THE GOLDERS GREEN TUBE EXTENSION. "INSLEY" CHUTING PLANT IN OPERATION.

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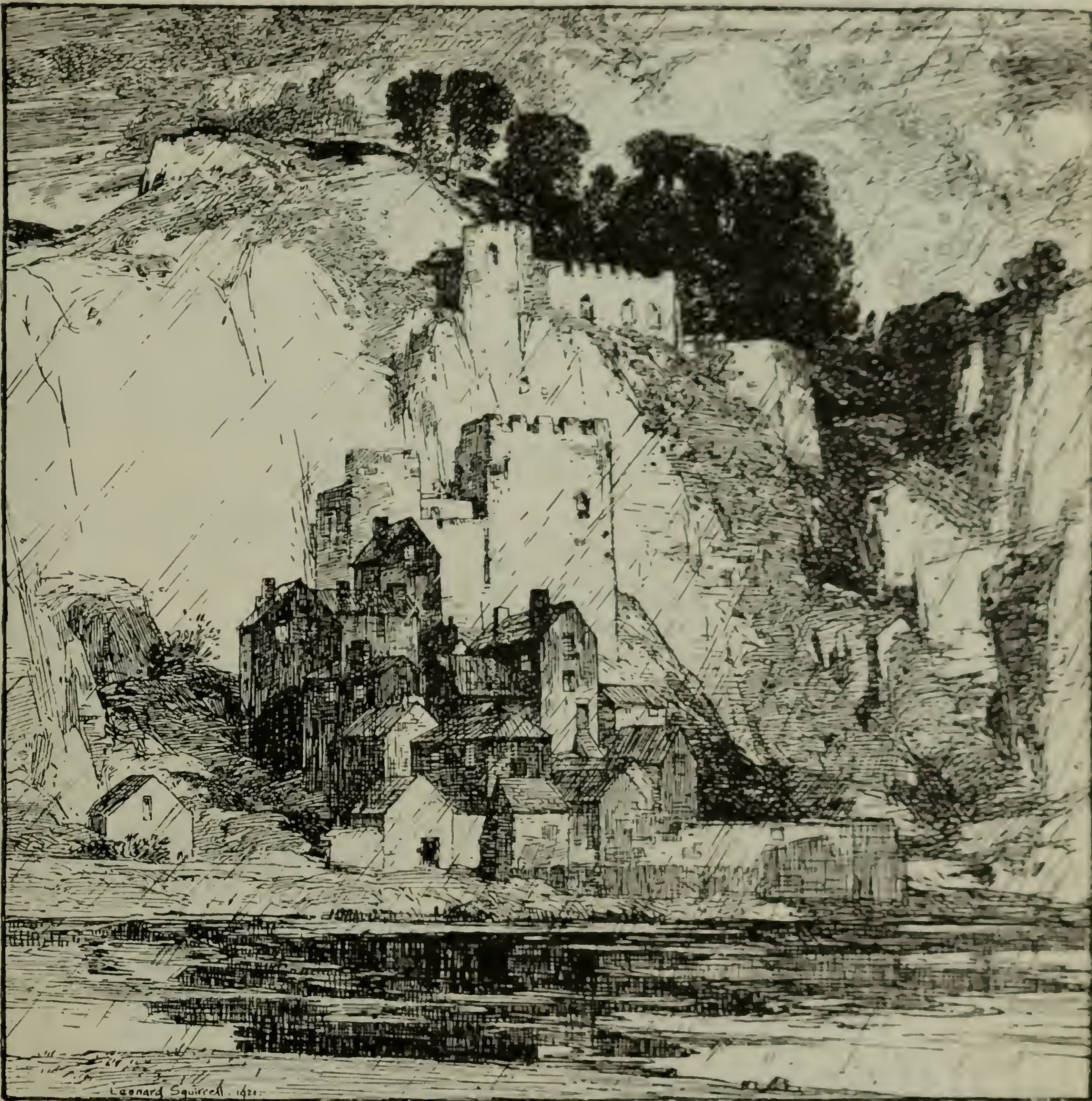
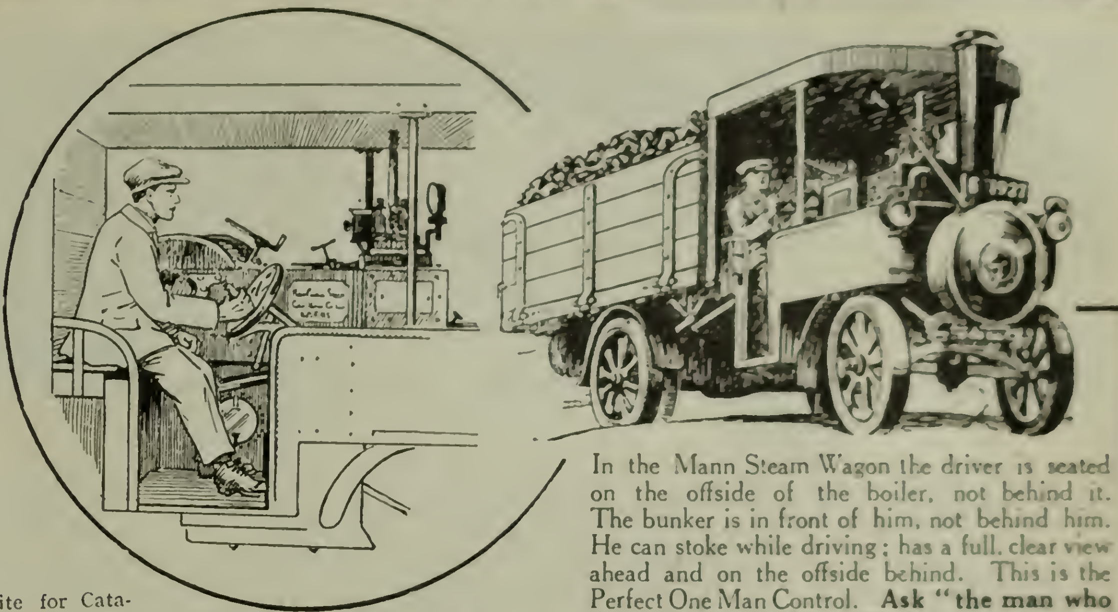
CONCRETE & CONSTRUCTIONAL ENGINEERING



Drawing by Leonard Squirrell, R.E.



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Coignet, Edmond, Ltd.
Considère Construction Co., Ltd.
Expanded Metal Co., Ltd.
Holliday & Greenwood, Ltd.
Holst, K. & Co.
Indented Bar & Concrete Engineering Co., Ltd.
Industrial Constructions, Ltd.
Johnson's Reinforced Concrete Engineering Co., Ltd.
Lind, Peter & Co.
Self-Sentering Expanded Metal Works, Ltd.
Yorkshire Hennebique Contracting Co., Ltd.

Concrete Machinery.
Allied Machinery Co., Ltd.
Australia Patent Concrete Block-Making Machine Synd.
Chalmers-Edina Co.
Gaston, Ltd.
Ransome Machinery Co. (1920) Ltd.
Stothert & Pitt, Ltd.
Tonkin Mixer.
Wilde, Henry, Ltd.
Winget Limited.
Wylie, Matthew, & Co.

Concrete Accessories and Equipment.
Blunn, J.
Brown & Tawse, Ltd.
Byrd, A. A. & Co.
Christmas, Hulbert & Walters, Ltd.
Cummings, C. B.
Gaston, Ltd.
Haynes, J. P., Ltd.
Helical Bar & Engineering Co.
Indented Bar & Concrete Engineering Co., Ltd.
Kennedy, W.
Leeds Oil & Grease Co.
Parker, Winder & Achurch, Ltd.
Ransome Machinery Co. (1920) Ltd.
Winget Limited.
Wylie, Matthew, & Co.

Concrete Road Plant.
Allied Machinery Co., Ltd.
Ransome Machinery Co. (1920) Ltd.

Concrete Road Reinforcement.
Barb Engineering Co.
British Reinforced Concrete Engineering Co., Ltd.
Brown & Tawse, Ltd.

Concrete Road Reinforcement—*continued.*
Expanded Metal Co., Ltd.
Indented Bar & Concrete Engineering Co., Ltd.
Johnson's Reinforced Concrete Engineering Co., Ltd.
Self-Sentering Expanded Metal Works, Ltd.
Walker-Weston Co., Ltd.

Concrete Chimneys.
Anglo-Danish Concrete Construction Co.
Chimneys Limited.
Monolithic and General Constructions, Ltd.

Concrete Blocks and Slabs.
London Phosphate Syndicate Ltd.

Cement.
Associated Portland Cement Manfrs. Ltd.
British Portland Cement Manfrs. Ltd.
Cement Marketing Co., Ltd.
Earle, G. & T., Limited.
Humber Portland Cement Co., Ltd.
Martin Earle & Co., Ltd.
Tunnel Portland Cement Co., Ltd.
Wouldham Cement Co., Ltd.

Concrete Aggregate.
Boyer, Wm., & Sons.
Croft Granite Brick & Concrete Co., Ltd.
Rom River Co., Ltd.
Stone Court Chalk Land & Pier Co., Ltd.
Trent Concrete Ltd.

Piling Plant.
Ransome Machinery Co. (1920) Ltd.

Steel Shuttering.
A. A. Byrd & Co. (Metaforms).
Climbing Steel Shuttering Co.
Gaston, Ltd.

Steel Piling.
British Steel Piling Co.
Ransome Machinery Co. (1920) Ltd.
Side Groove Steel Piling Supply Co., Ltd.

Tar Macadam and Asphalt Plant.
Ransome Machinery Co. (1920) Ltd.

Publications.
Concrete Utilities Bureau.
Concrete Publications Ltd.

Various.
Building Products Ltd. (Prufit, Ferrolithic).
Kerner-Greenwood & Co., Ltd. (Pudlo).
Mann's Patent Steam Cart and Wagon Co., Ltd.
Reah Brothers.
Ruberoid (Roofing).
Super-Cement Co., Ltd.
Tidnams, Ltd.
Torbay & Dart Paint Co., Ltd.

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